NPSOR-91-023

NAVAL POSTGRADUATE SCHOOL

Monterey, California

APPLICATION OF THE MODULAR COMMAND AND CONTROL STRUCTURE (MCES) TO MARINE CORPS SINCGARS ALLOCATION

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August 1991

Prepared for:
Warfighting Center
Marine Corps Combat Development Center
Quantico, VA 22134-5001

NAVAL POSTGRADUATE SCHOOL,
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Unclassified

Security Classification of this page

REPORT DOCUMENTATION PAGE

1a Report Security Classification UNCLASSIFIED	1b Restrictive Markings
2a Security Classification Authority	3 Distribution Availability of Report Approved for public release; distribution is unlimited.
2b Declassification/Downgrading Schedule	
4 Performing Organization Report Number(s) NPSOR-91-23	5 Monitoring Organization Report Number(s)
6a Name of Performing Organization Naval Postgraduate School — 6b Office Symbol *(If Applicable)* OR	7a Name of Monitoring Organization Naval Postgraduate School
6c Address *(city, state, and ZIP code)* Monterey, CA 93943-5000	7b Address *(city, state, and ZIP code)* Monterey, CA 93943-5000
8a Name of Funding/Sponsoring Organization Warfighting Center Marine Corps Combat Development Center — 8b Office Symbol *(If Applicable)*	9 Procurement Instrument Identification Number M9545091WRR1AKZ
8c Address *(city, state, and ZIP code)* Quantico, VA 22134-5001	10 Source of Funding Numbers

Program Element Number	Project No	Task No	Work Unit Accession No

11 Title *(Include Security Classification)* Application of the Modular Command and Control Structure (MCES) to Marine Corps SINCGARS Allocation

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13a Type of Report	13b Time Covered	14 Date of Report *(year, month,day)*	15 Page Count
Technical	From To	1991, July	

16 Supplementary Notation The views expressed in this paper are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17 Cosati Codes			18 Subject Terms *(continue on reverse if necessary and identify by block number)*
Field	Group	Subgroup	Evaluation; command, control and communications (C3); SINCGARS; networks; simulation

19 Abstract *(continue on reverse if necessary and identify by block number*

The Modular Command and Control Evaluation Structure (MCES), contains seven steps for the evaluation of C3 systems. In this paper the application of these steps is described in general. Then their potential application to Marine Corps POM C3 issues is discussed in general terms. Finally the more detailed applications to the allocation of Marine Corps tactical voice radios is discussed. An object-oriented model developed at NPS is briefly described.

20 Distribution/Availability of Abstract	21 Abstract Security Classification
[X] unclassified/unlimited [ ] same as report [ ] DTIC users	Unclassified

22a Name of Responsible Individual	22b Telephone *(Include Area code)*	22c Office Symbol
M. G. Sovereign	(408) 646-2428	OR/Sm

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted — security classification of this page

All other editions are obsolete — Unclassified

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TASK 1A MCES REVIEW & MEB APPLICATIONS

A. INTRODUCTION

The (MCES) is a general approach to evaluating C3 systems which has been successfully applied to a number of issues concerning C3 system planning, acquisition, testing and operation. It augments traditional analysis by providing a series of seven steps or modules to evaluate alternative C3 systems and architectures. These modules guide analysts who might otherwise focus prematurely on the quantitative model rather than the problem definition and the specific measures needed to discriminate between alternatives. The seven steps of the MCES are briefly described below including the product of each module.

The MCES begins by identifying the objective of a particular application. This leads to a formal problem statement. The second step is to bound the C3 system involved, by producing a complete list of system elements at several levels. The third step is building a dynamic framework that identifies the relevant C3 process—a set of functions. These are derived from the generic control loop (cybernetic) model of C3. The fourth step combines the results of steps two and three by integrating the system elements and the process functions into a model or representation of the C3 system. The product of this module is at least a complete descriptive conceptual model and sometimes a complete mathematical model. The next (fifth) step is to specifically identify measures of performance, effectiveness and force effectiveness at the corresponding levels of the C3 system and function. The

sixth step is to generate results or values for these measures by testing, simulation, computational modeling or subjective evaluation. Finally, the various measures are aggregated and interpreted in the last step. Each of those steps is described as a module below.

In a new area such as C3, standard language and paradigms are difficult but necessary. The MCES was developed by a team of experts from industry, government and academia and was endorsed by the Military Operations Research Society. It presents difficult concepts in a standardized way that is easily absorbed by both new practitioners and managers. MCES has potential for reducing mis-understandings of the purpose and mis-applicability of analytical results. This is important when issues of great diversity of nature, size and level of detail are being considered, such as in preparation of the Program Objective memoranda (POM). Standardization of analytical procedure can be advantageous if based on a comprehensive and rigorous methodology such as MCES. MCES can be used for studies ranging from the quick conceptual level to the complete quantitative study. It is difficult if not impossible to require a complete quantitative study for each issue during a POM cycle, as is required for acquisition cycle issues with the Cost and Operational Effectiveness Analysis (COEA). But application of the MCES at even the conceptual level of analysis may allow better articulation of POM tradeoffs. The next section is an exposition of the substance of the MCES. This serves as preparation for the required interpretation of the MCES in terms of the MEB C3 problem as specified in Task 1. It will then be followed by application of the MCES to the allocation of SINCGARS as also required in Task 1.

The seven steps of the MCES are performed iteratively with the decision maker as shown in Figure 1. Iteration is an important concept which

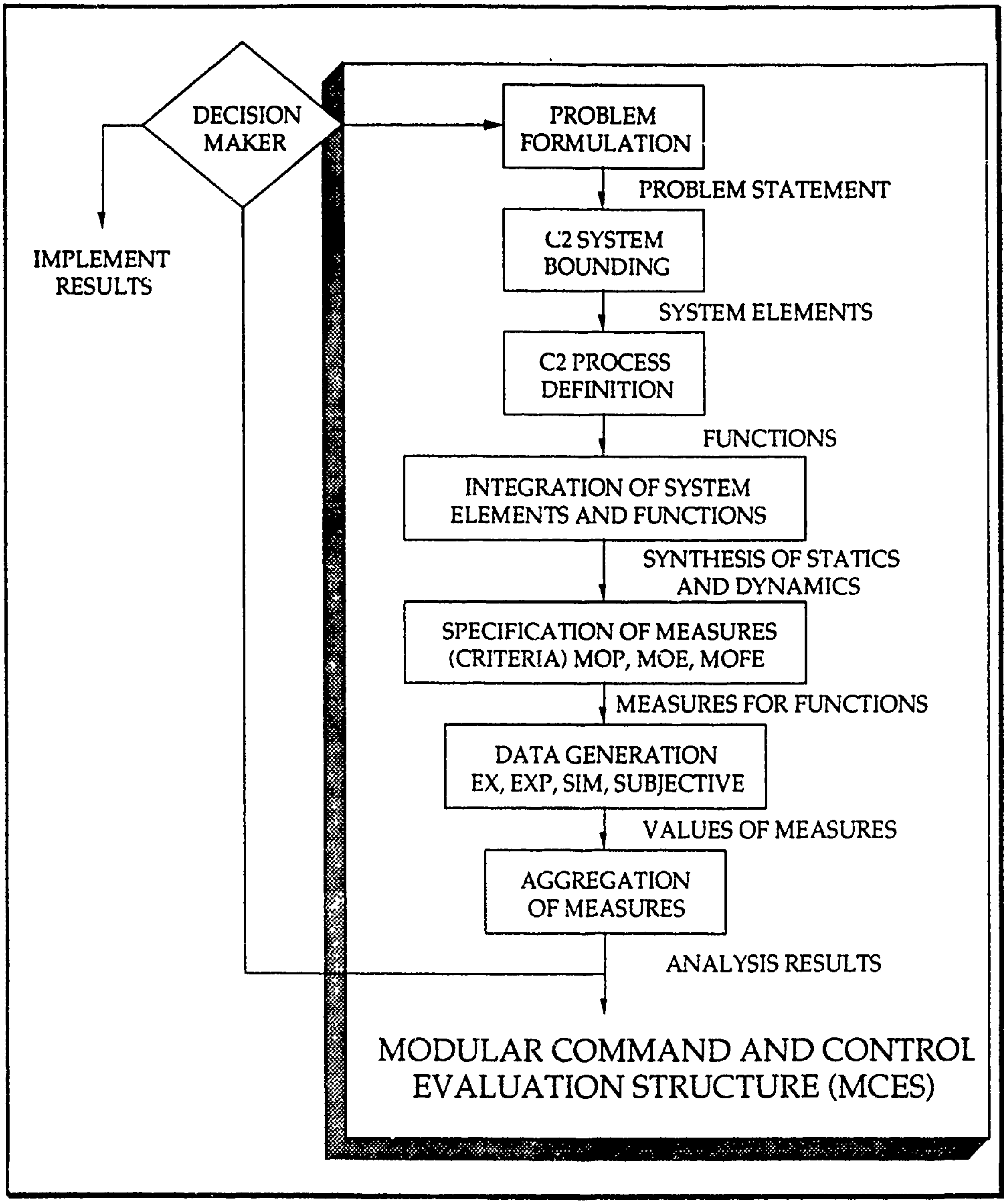

Figure 1. Modular Command and Control Evaluation Structure

prevents "paralysis by analysis." Iterative refinement of the problem and analysis helps both the decision maker and the analyst to prevent studies from being overtaken by events. The outputs of each step are also shown in Figure 1. Each of the steps or modules is explained below.

B. MCES MODULES

1. Module 1: Problem Formulation

Module 1 describes the decision maker's objective and the context for a specific C3 problem as shown in Figure 2. In it the formal decision process (if any), the policy assumptions and the scope and depth of analysis are defined. The identification of the full set of decision makers being addressed may be necessary. In this module both the appropriate mission and scenario(s) are made explicit. The output, a precise statement of the problem, is used in the second module to bound the C3 system of interest.

The objectives of the decision maker(s) posing the problem are identified in terms of the life cycle of the C3 system and the level of analysis prescribed. The decision maker's objectives generally reflect the various phases of the life cycle of the C3 system, namely: (1) concept definition and/or development; (2) design; (3) acquisition; or (4) operations. The appropriate level of analysis is derived from: (1) the mission the system is addressing; (2) the type of system itself; (3) the timing, scope and criticality of decision; and (4) the background and commitment of the decision maker(s). In this problem formulation step, it is wise to make an initial pass at all the MCES steps with the objective of identifying the range of likely answers for each module. This helps scope the analytical effort as early as possible.

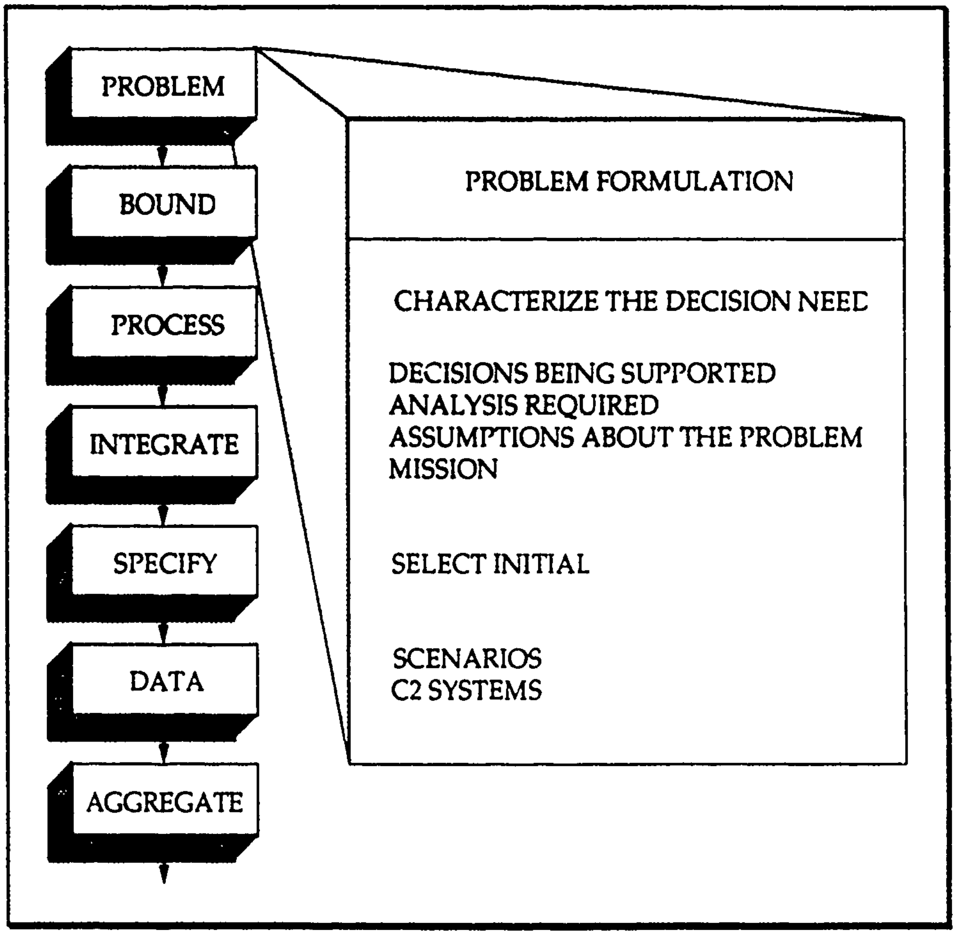

Figure 2. MCES Problem Formulation

In the implementation of this step, the answers to several questions may provide guidance, namely:

1. Who is/are the decision maker(s), and how and when will the decisions be made?
2. What mission area is involved? Must joint or combined forces be addressed?
3. What communities/viewpoints must be addressed for acceptance?
4. What are the basic assumptions of the problem? Classification level? Historically how has the problem been solved?
5. Does the evaluation apply to an individual C3 system or require a comparative evaluation of several alternative systems and/or forces?

6. What threat and scenarios are appropriate and available?
7. What part of the life cycle of the C3 system is involved? Time frame?
8. What level (system, subsystem, platform, force, etc.) is the analysis focused upon?
9. What type of measure, i.e., how quantitative, will answer the decision maker's question?
10. What analytical support will be required? Testing? Simulation?

In summary, three steps take place in Module 1: (1) the decision maker's needs are characterized; (2) the problem's scope and depth are selected; and (3) the remaining modules are previewed for their potential impact on the problem statement and analytical effort required.

2. Module 2: C3 System Bounding

Module 2, as described by Figure 3, enumerates the relevant system elements that bound the problem of interest. The first goal is to delineate the difference between the system being analyzed and its environment. To bound the C3 system, the analyst should employ the three-part definition, based upon JCS Publication 1. In it, a C3 system consists of: (1) physical entities—equipment, software, people and their associated facilities; (2) structure—organization, concepts of operation, standard operating procedures, and patterns of information flow; and (3) process—the functionality or "what the system is doing" which is pursued in Step 3. In the second module the C3 system, identified by its human, hardware and software entities and structures, is related to the forces it controls and the environmental stimuli to which it responds, including the enemy. Once the system elements of the problem have been identified, the C3 system of interest may be further bounded by relating the "physical entities" and the

structure components to the graphic representation of the levels of analysis, using the graphic model as shown in Figure 4.

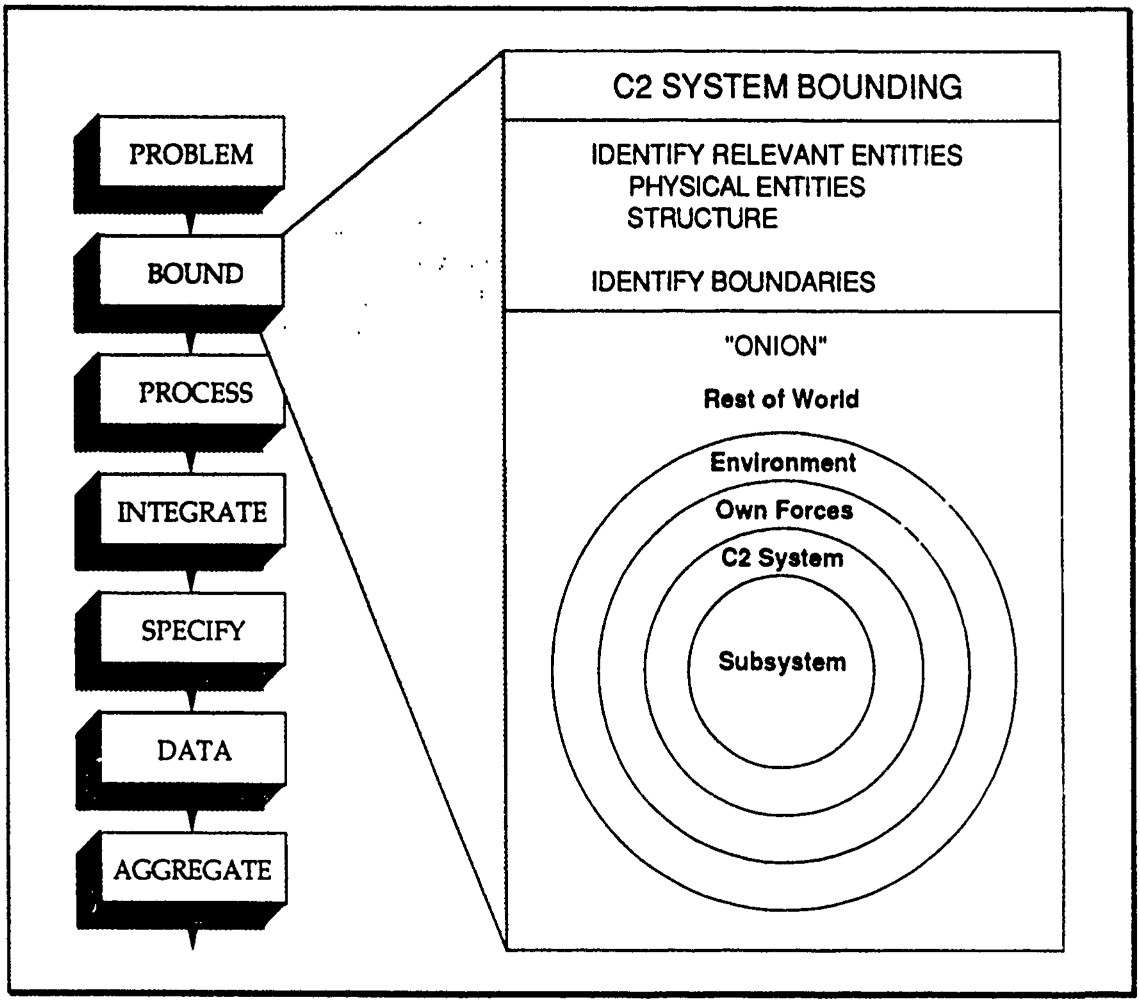

Figure 3. MCES C2 Systems Bounding

This series of levels is referred to as the "onion skin." In the most inclusive depiction of this graphic, there are five rings. Beyond the outer ring is the rest of the world, which essentially relates to elements and structure that exist and may have import with respect to similar problems, but which are outside the scope of the problem at hand. In contrast, the outer ring

represents the environmental factors that require explicit assumptions in the problem. This ring may be seen as including the major scenario components. The next ring, moving inward, deals with the forces under influence of the C3 system upon which the evaluation is centered. The C3 system itself is the focus of the next ring, and its component subsystems make up the innermost ring. As is clear from the foregoing, this graphic is a structured static display of the physical entities.

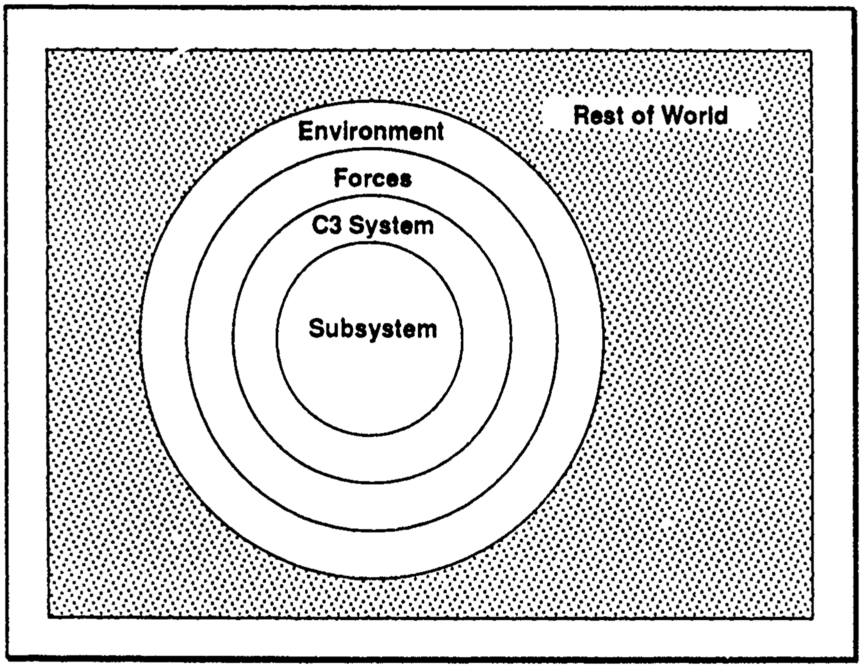

Figure 4. C3 System Bounding and Level of Analysis

In summary, 1) the C3 system statics must be distinguished from the C3 system dynamics, the "C3 process" and its functions. 2) The statics must be be listed as the physical entities together with the structural relationships of C3. 3) The structure is represented by the customary physical arrangement and interrelationships of entities in the form of command structure, the standard operating procedures, protocols, message formats and reporting requirements. Bounding the C3 system often leads to broadening the system of interest. It

may be necessary to consider the source of information as well as the display that is being decided upon in a particular decision.

3. Module 3: C3 Process Definition

After the system is bounded and the system elements identified, the dynamic C3 processes of the system are identified as noted in Figure 5.

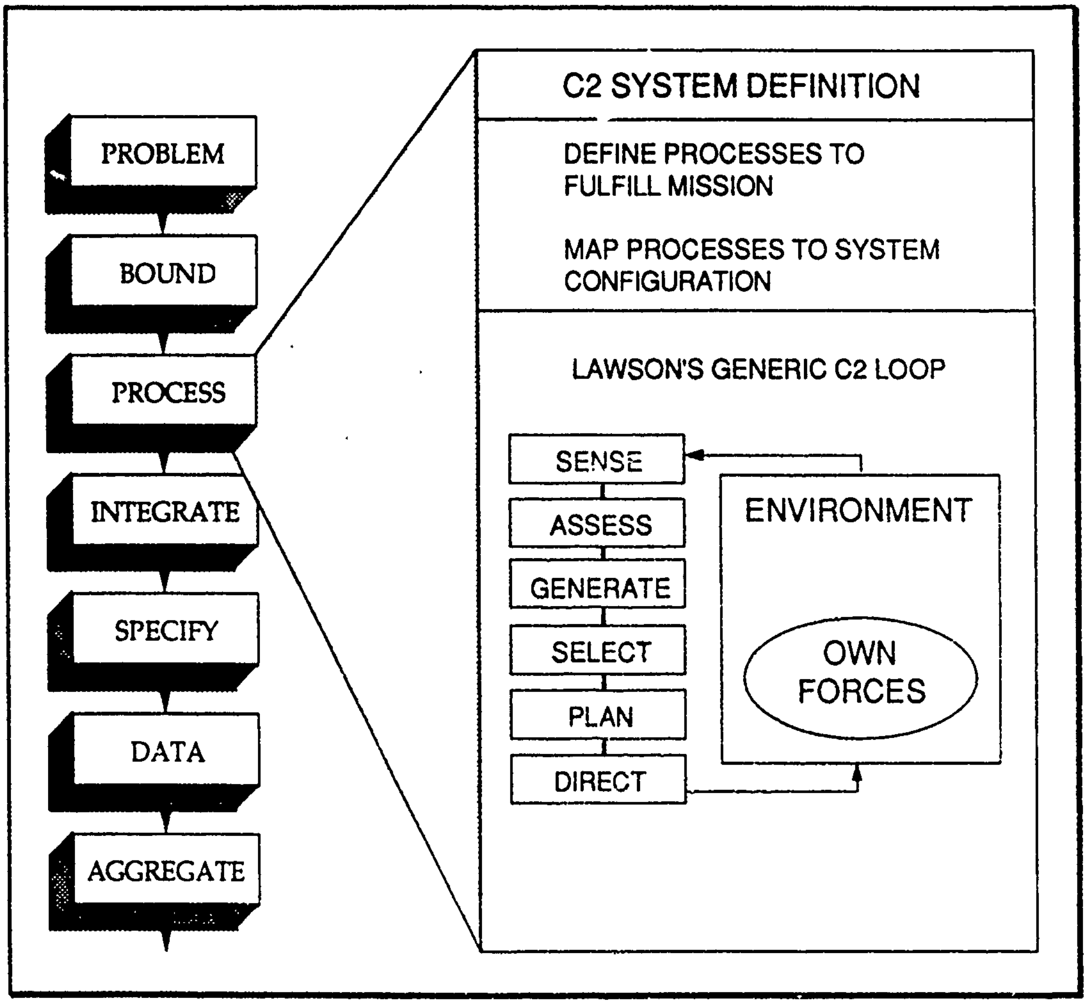

Figure 5. C2 Process Definition

Module 3 focuses the analyst's attention on: (1) the environmental "initiator" of the C3 process, which results from changes in the desired state, usually of enemy forces; (2) the internal C3 process functions (sense, assess,

generate, select, plan, direct); and (3) the input to and output from the internal C3 process and the environment. The C3 process functions are generic and may be adapted to the specific functions of air defense, ground operations etc. They can be described briefly here as six function.

- Sense—the function that collects data necessary to describe and forecast the environment, which includes:
  - (1) The enemy forces, disposition and actions.
  - (2) The friendly forces, disposition and actions.
  - (3) Those aspects of the environment that are common to both forces—for example, weather, terrain and neutrals.
- Assess—the function that transforms data from the sense function into information about intentions and capabilities of enemy forces and about capabilities of friendly forces to determine if deviation from the desired state warrants further action.
- Generate--the function that develops alternative courses of action to correct deviations from the desired state.
- Select—the function that selects a preferred alternative from among the available options. It includes evaluation of each option in terms of criteria necessary to achieve the desired state.
- Plan—the function that develops implementation details necessary to execute the selected course of action.
- Direct—the function that distributes decisions to the forces charged with execution of the decision.

In summary, these six functions have been found to be sufficiently comprehensive to map to almost any C3 process. They are applied iteratively.

4. Module 4: Integration of System Elements and Functions

As noted in Figure 6, in Module 4 the relationships between the physical entities and structures (defined in Module 2) and the C3 processes or functions (described in Module 3) are first identified and described—who does what, when. Then techniques such as PERT charts, data flow diagrams or

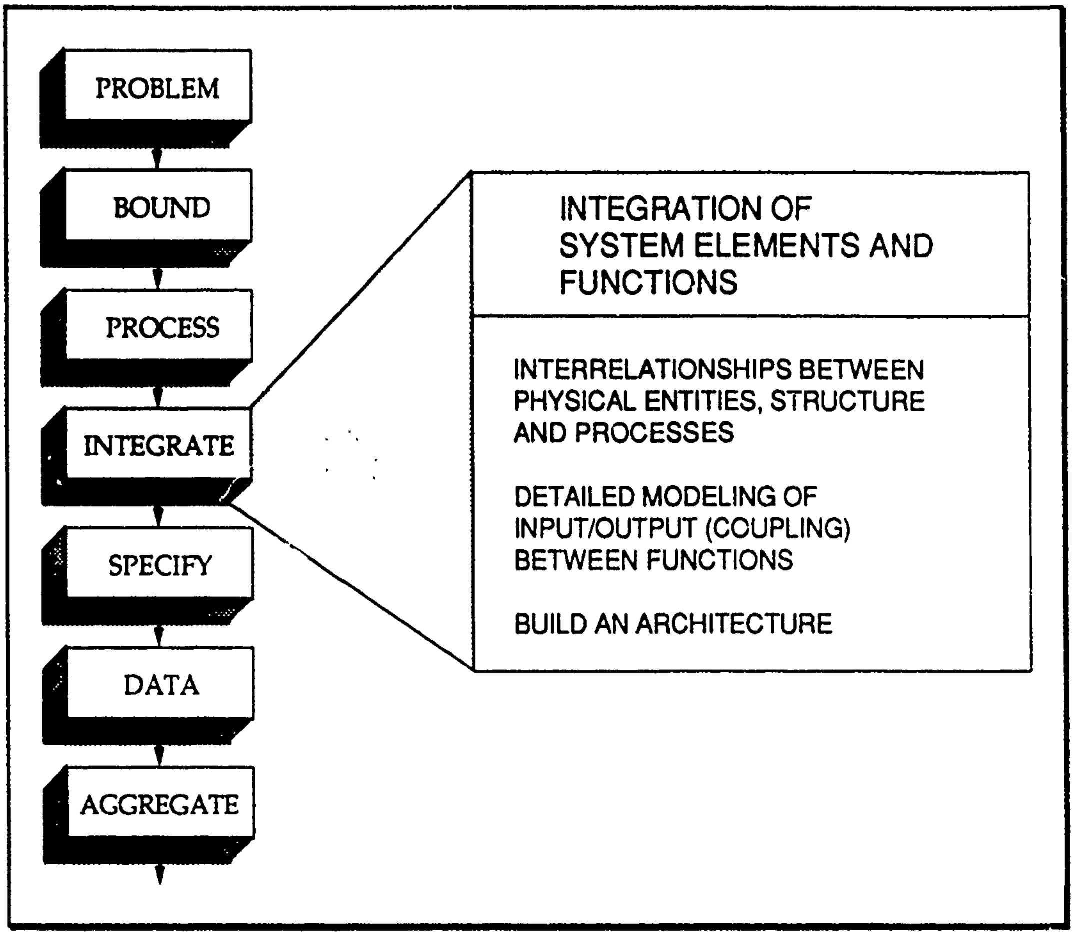

Figure 6. Integration of System Elements and Functions

Petri nets may be used to model the messages or information flows that are used to control these relationships. Information flows support decisions that link the separate C3 functions into the architecture containing the relevant C3 system. The term "architecture" is used to describe the output of module 4 to emphasize the integration via defined interfaces and standards of the individual C3 subsystems. The physical entities, structures and functions of these individual systems are coherently controlled in a dynamic architecture. The architecture might indeed become a functioning computer model of the system which would support an evaluation of mission effectiveness. The final form of the architecture will at least include the process description of

the system elements performing the processes arranged in a structural framework as indicated in Figures 3-4. These may be adequate to support qualitative evaluation of the architecture. A quantitative description of the elements and the inputs to the processes are required even if a model cannot be built in the time available. Even these descriptive inputs allow an informal assessment on a subjective basis. In summary this module maps Steps 2 and 3 together and provides quantitative information preferably as a model of the architecture in a static and/or dynamic mode.

5. Module 5: Specification of Measures

A C3 measure can usually be categorized as either a performance measure or a vulnerability measure. There are generic sets of both of these categories such as the TRI-TAC MOEs shown in Table 1. These TRI-TAC measures are generic and need additional specification in terms of a particular scenario and C3 system. For example, the units of speed of service, interoperability and survivability must be identified with reference to the mission and level of the system.

TABLE 1. TRI-TAC MEASURES OF EFFECTIVENESS

PERFORMANCE MEASURES	Grade of service Information Quality Speed of Service Call Placement Time Service Features Lost message Rate Spectrum Utilization Transportability Mobility Ease of Reconfiguration Ease of Transition Interoperability
VULNERABILITY MEASURES	Index of Survivability (Overt) Index of Survivability (Jamming) Index of Availability Interrupt Rate Security

In Module 5, as illustrated in Figure 7, the analyst specifies the measures necessary to answer the problem of interest as defined in Module 1 and in the system bounding process and integration. The component levels and functions of the C3 system definition modules may be examined to derive an initial set of relevant measures, which are then subjected to further scrutiny: (1) comparison with a set of criteria, Table 2, which may reduce the number to a more manageable set; (2) the remaining measures are then classified as to their level of measurement (MOFE, MOE, MOP or parameter) which may lead to association of some to a lower level than currently of interest; (3) mapping of the MOFE to related MOEs and then to related MOPs, etc., and (4) the resulting high level measures are examined for the practicability of measuring alternative configurations of the physical entities, structure and/or processes of the C3 system in the scenarios defined in Module 1. Practicality often drives measurement down to the level of MOE or even MOP because combat oriented measurements are inherently difficult.

TABLE 2. CRITERIA FOR EVALUATION MEASURES

CHARACTERISTICS	DEFINITION
Mission-oriented	Relates to force/system mission
Discriminatory	Identified real differences between alternatives
Measurable	Can be computed or estimated
Quantitative	Can be assigned numbers or ranked
Realistic	Relates realistically to the C2 system and associated uncertainties
Objective	Can be defined or derived, independent of subjective opinion
Appropriate	Relates to acceptable standards and analysis objectives
Sensitive	Reflects changes in system variables
Inclusive	Reflects those standards required by the analysis objectives
Independent	Is mutually exclusive with respect to other measures
Simple	Is easily understood by the user

Each of the three levels of the C3 system in the onion-skin diagram is directly related to measures of performance (MOPs), measures of effectiveness (MOEs), and measures of force effectiveness (MOFEs) as shown in Figure 7.

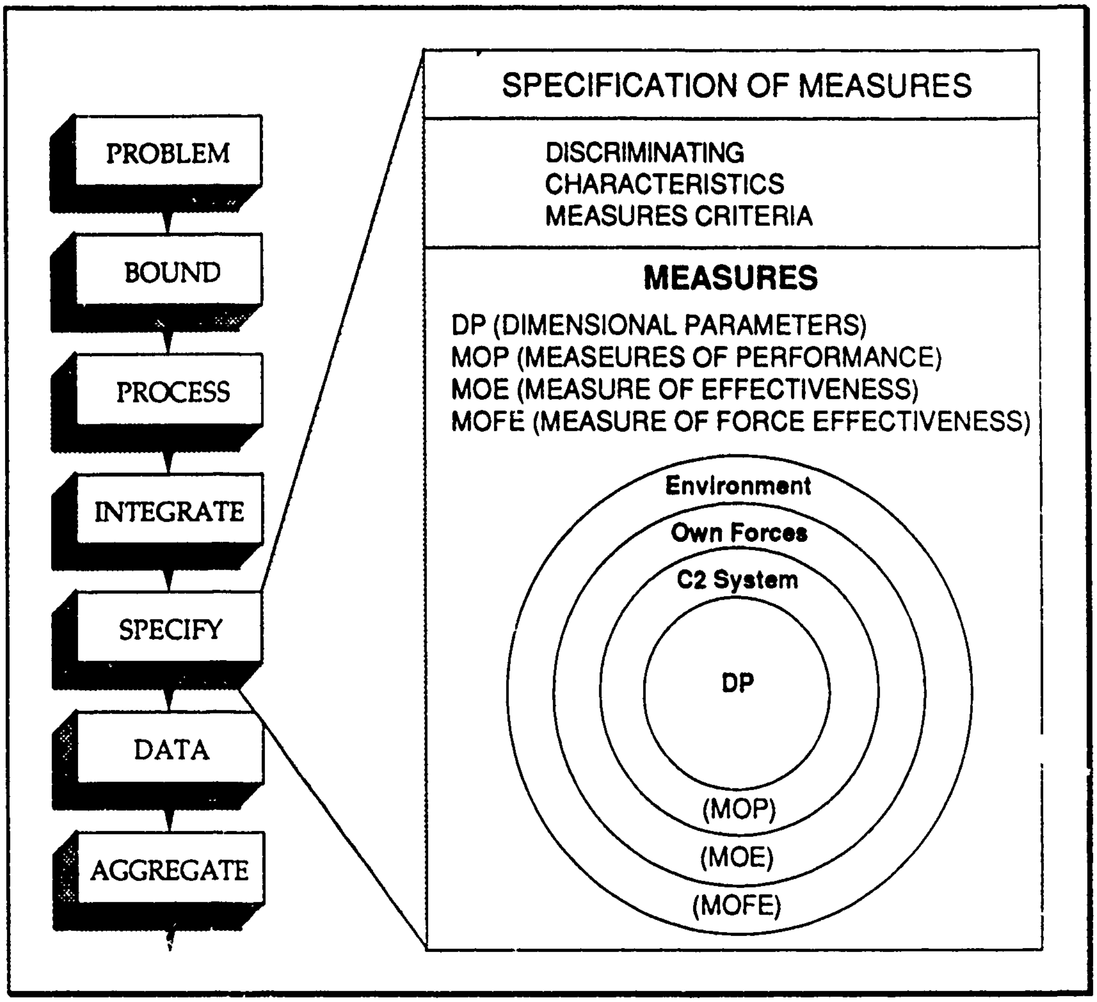

Figure 7. Specification of Measures

The determination of the boundary helps to identify what level of measure is appropriate. If the boundary between the force and the environment is of interest, measures of force effectiveness (MOFE) are required. Dealing with the boundary between force and the C3 system leads to

measuring the effectiveness (MOE) of the C3 system. At the subsystem level—that is within the boundary of the system—are measures of performance (MOP) of the functions. Finally, within the subsystem are Dimensional Parameters (DP). Measures at the higher level, MOFEs and MOEs, are most desirable because they are closer to the ultimate purpose of the C3 system and because they summarize many of the lower level measures in a meaningful way.

In summary, this module's implementation results in the specification of a set of measures that is focused on the C3 process functions within the C3 system, the overall performance of the C3 system and on the force effectiveness of the C3 system combined with the forces and weapon systems, if at all practical.

6. Module 6: Data Generation

The generation of values for the measures determined in the previous module is addressed by the sixth module. These values are the result of the implementation of this module as noted in Figure 8. Here, one of several types of data generators such as exercises, experiments, simulations, models or subjective judgement is selected. The MCES accommodates a variety of data generators. The prime requirements are that the data generator is: (1) available to the analysis; (2) focused on the mission area/analysis objectives of the evaluation; and (3) adaptable to produce, with minimal modification, the values associated with the measures specified in the previous module. The analyst must consider the following: reproducibility of results, precision and accuracy, costs and timing of data collection, environmental controls, and experimental design in the final choice of how to generate the values.

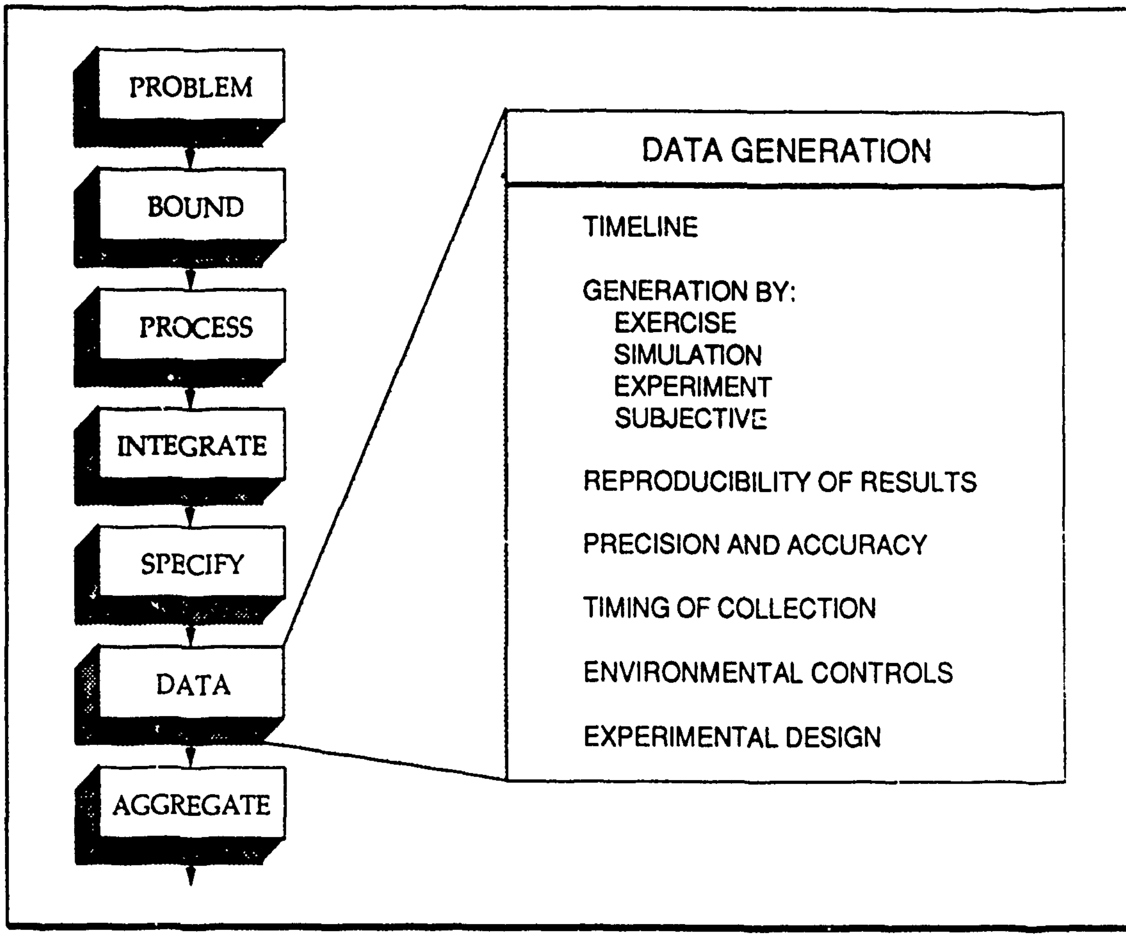

Figure 8. Data Generation

This step is directly supported by Module 4, the integration of elements and processes. If the integration has resulted in a quantitative model it will be straightforward to generate output data. The verification of input data from modules 2 and 3 and validation of the model must also be addressed. Alternatively, if only a conceptual mapping of function to structure is accomplished in Module 4, the generation of values for measures may be only a qualitative comparison table or relative judgmental statements by experienced personnel.

In the typical implementation, the relationships established in module 4 are translated into computer code. In this process it will often be necessary to define additional relationships and obtain more input data. The validation and verification of this code as a representation of the problem must also be addressed. The National Test Bed's Confidence Assessment Methodology is a recommended reference for this step.

7. Module 7: Aggregation of Measures

In Module 6, Data Generation, the analyst obtains values for the specified measures which will be analyzed and interpreted in this module as noted in Figure 9. Because varying scenarios may be important for each iteration of the MCES, the analyst must determine the importance of each factor. The final module addresses the issue of how to aggregate and interpret the measures. Three levels of measurement (performance, effectiveness and force effectiveness) with multiple values from each level may be available. The current state of the art requires that both qualitative (such as red-yellow-green charts) and quantitative (such as utility weighting) aggregation techniques be considered.

The nature of the problem and available tools determine the mix of these techniques. Different problem areas addressing different decision makers' analytic needs will result in differing requirements for aggregation of constituent measures, but the mappings between levels allow the decision maker to make an informed decision and understand the reasons for it. The issues of measure causality, sufficiency and independence must be considered. The analyst must decide if the decision maker's original queries have been

addressed by the MCES analysis. Finally, suitable graphics should be prepared for interaction with the decision maker.

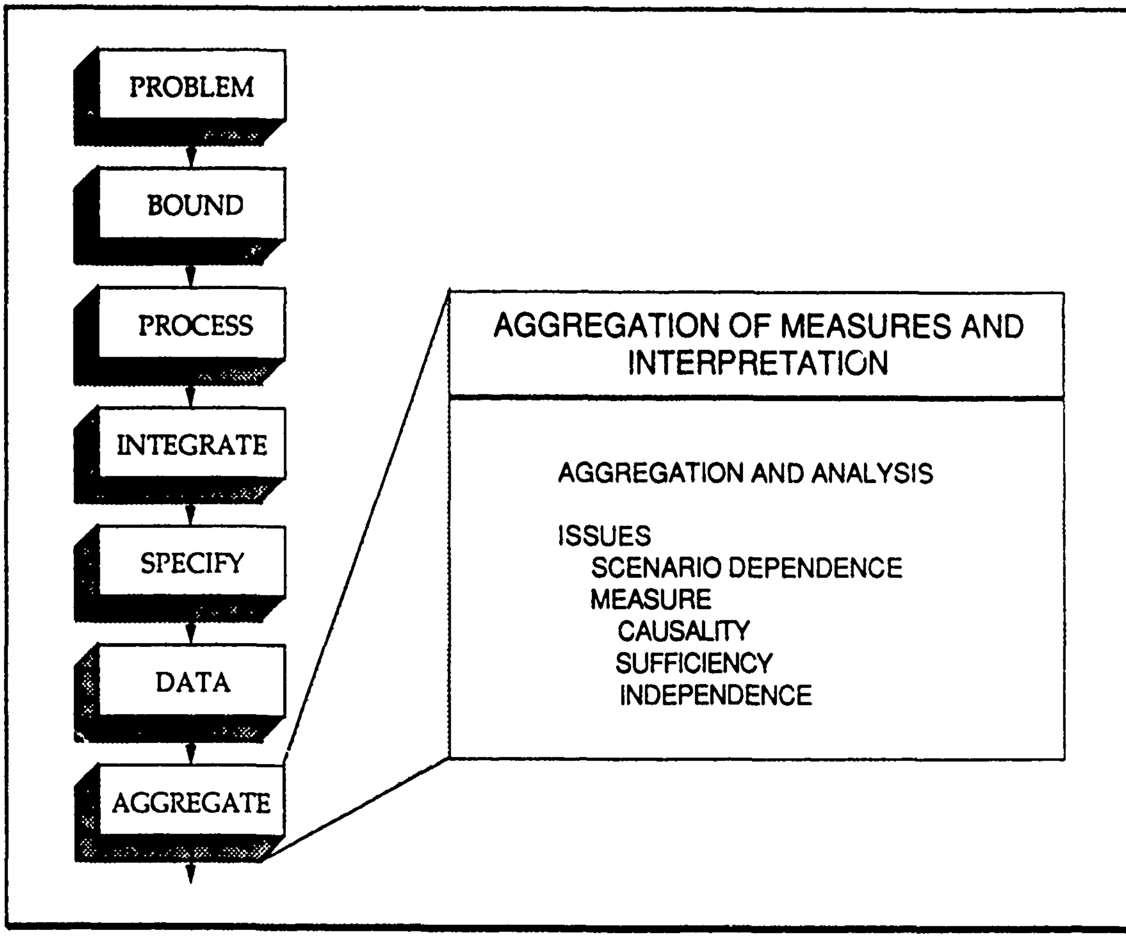

Figure 9. Aggregation and Interpretation of Measures

The implementation of this module provides the analytical results tailored to address the problem posed at the beginning of the procedure. The results, made up of the aggregated values and measures, should be provided to the decision maker in a format that will expedite his consideration of the analysis. Whenever appropriate, graphics are used to summarize and show trade-offs.

Finally the results are provided to the decision maker. Two courses of action are available. First, the decision makers may identify the need for further iteration. Or they may proceed to implement the decision. In most situations, explanation of objectives and the reasoning behind the decision help the implementation by lower levels of the organization. MCES is an aid in conveying the context, structure and evidence supporting the decision to these levels.

C. ILLUSTRATION: POTENTIAL APPLICATION OF THE MCES TO THE MARINE CORPS POM PROCESS FOR C3 ISSUES

1. Introduction

The MCES may be of value as a means of structuring analysis for POM decision-making regarding MEB C3 issues. This section will discuss possible advantages of the MCES in the POM environment, which has been briefly witnessed by one of the research team members. It will be followed by a general discussion of the difficulty of POM tradeoffs and in later sections by a description of how such issues might be treated in each module of the MCES. Later the MCES will be applied to the SINCGARS allocation problem in a detailed manner leading up to an example of analysis of the SINCGARS similar to that which could be accomplished for POM issues of particular significance.

The discussion is limited to MEB C3. Broader issues clearly exist in the POM but the MEB is a reasonable focus for a mission-oriented approach such as MCES, which was designed for addressing single issues. If the MCES approach to the MEB-level POM issues seems meritorious, projections of application to broader issues could be developed.

One of the difficulties of decision making in the POM process is the wide variation in scope and level of the competing POM initiatives, i.e., roughly 1 million to 100 million dollars in yearly costs. MCES may be of benefit in three ways: (1) standardized identification of mission and function so that the area of impact of the initiative can be pinpointed, (2) relative assessment of the contribution of the initiatives to solution of the problems they address in their area; and (3) highlighting of potential interface and interoperability issues or synergistic benefits of individual initiatives. Each of these three is discussed below.

The first contribution of MCES is to provide a means of narrowing the scope of each decision by identifying the areas affected by an initiative. This will prevent sponsors of initiatives from citing benefits of all kinds to everyone. Although this claim may be true to some extent, this approach hampers decision-making. Even a quick, qualitative application of the MCES results in an identification of the major applicability of an initiative. The MCES requires identification of the following for each POM initiative:

1. mission area affected
2. command center elements impacted
3. C3 architectures impacted
4. C3 processes and procedures affected
5. major C3 hardware and software systems affected
6. possible environmental constraints (all-weather, etc.),
7. time frame of contributions in the field,
8. measures of force effectiveness, C3 system effectiveness and subsystem effectiveness appropriate for measuring the impact,
9. a first cut of what would be necessary to generate the data to measure the impact of the initiative, and

10. a first cut at an aggregation of the information necessary to decide on the cost effectiveness of the initiative.

If this information could be systematically available for each alternative, it is likely that POM decision making could be more well-structured and would waste less time on irrelevant definitional problems or third-order claims of contribution.

As a simple example, consider Table 3. The two-dimensions of the table are very aggregated mission by aggregated C3 function. Even at this level it would be possible to identify the areas impacted by each initiative with time frame of impact coded by short, mid or long term within the table. This would enable decision makers to see the distributions of effort across mission and C3 process and to identify possible overlaps, duplication or holes in the total effort.

TABLE 3. ILLUSTRATIVE MCES-POM DISPLAY

AGGREGATED C3 PROCESS FUNCTIONS	AGGREGATED MISSIONS			
	COMMAND	AIR COMBAT	GROUND COMBAT	CSS
1. Acquire Information				
2. Process Information				
3. Disseminate Information a. Connectivity b. Delay c. Vulnerability				

Addition of an assessment for the POM of the threat, baseline capability and relative deficiency or net assessment of current capability in these categories would be helpful in translating this table into decision making. Of course finer division of mission and C3 process could contribute to the identification but might make it more difficult to make the net assessment. Additional dimensions from the list of ten above could also be added.

Although this information could be collected without MCES, the rigor of the MCES avoids distortion produced by sponsors' enthusiasm for their initiatives.

In addition to the identification of the area of contribution of the initiative, the MCES can give qualitative or quantitative assessments of how much impact the initiative can make. A full quantitative analysis such as will be illustrated for SINCGARS would be preferable but may not be possible in the time-constrained POM environment. However, a qualitative analysis can be performed relatively quickly. If presented in standardized MCES form, these analyses could serve as the basis for judgmental or group decision-making efforts to categorize the impact as: significant, marginal or negligible in each relevant area, for example. With the cost of each initiative known, as it is for most POM initiatives, relative cost-effectiveness could also be assessed by the same qualitative methods.

Again these qualitative assessments could be done without the MCES but the systematic rigor of MCES encourages critique of each initiative's weak points and identifies incompleteness. It also makes clear how much additional effort would be required to obtain dependable assessments and therefore highlights the real uncertainty in the benefits of the initiatives.

Another way in which MCES contributes to the relative assessment of the contribution of the initiatives, even without complete quantifiable measurement, is the identification of measures of performance, measures of C3 effectiveness and/or measures of force effectiveness for the initiative. Even without knowing the quantitative values of these, it may be possible to compare several initiatives simply by their obvious qualitative differences in

impact on these same measures. Experience has shown that doubling of measures of performance will generally have a much lower impact on measures of C3 effectiveness (perhaps a 10-50% improvement) and only a very minor impact on measures of force effectiveness (a few percentage points) This gives some idea of a threshold for effectiveness of initiatives at the measure of performance level. When costs of the initiatives are known, it can also give a very rough indication of cost effectiveness because a C3 initiative that represents a large increase in the cost of a total force can rarely be recovered in increased force effectiveness (Achilles heels excepted).

The third contribution of the MCES to POM assessment of initiatives is the identification of interfaces of the initiatives with the existing C3 system. This can be useful in two distinct ways. It helps identify what other C3 systems or processes will probably have to be improved in order to take advantage of the initiative (or to make the initiative actually pay off). Often these impacts are overlooked by the sponsors of initiatives. It can also indicate where interoperability must be carefully considered if the effectiveness of the initiative is not to be totally lost because of inability of other areas to meet the interface requirements. Incompatibilities of bit vice character-oriented systems, data rates, message formats, etc., are also often overlooked. These can add significantly to the final costs of C3 initiatives, as can training in new processes or procedures which can also be identified by the MCES.

2. Problems in C3 POM Decision Making

One of the first steps in dealing with a problem is to formulate the problem in such a manner that it will be possible to determine when an

answer has been identified. This involves a dilemma. One the one hand everyone wants crisp definitive answers which will be immutable. On the other hand everyone wants to keep their options open and not make important decisions until necessary. The first leads to overly specific, detailed answers to yesterday's problems. The latter leads to bland statements of general principle without narrowing the scope of the problem. In the POM environment it is easy to avoid decisions by delay and program stretch-out rather than cancellation.

In general, MEB C3 problems can be described as the inability to ensure that all levels of command will have convenient access to the information needed to make timely decisions under all combat conditions. In the POM environment it is easy to forget that more equipment is not necessarily the answer. The ability to make good MEB C3 resource allocation decisions in the POM requires selecting those systems which blend simplicity and flexibility of performance with the benefits of newer technology including training and supply constraints. For example an excellent system which requires specialized training should not be assigned to frontline units where the only specialist may likely become unavailable. Selection and allocation of new systems must be harmonized with the totality of the existing complex C3 system. For example while information must be guarded from disruption by the enemy, disruption can also occur from inadequate planning for the tactical implications, doctrinal deviations and excessive training load of inappropriate new systems or procedures.

Since C3 is a total system, the interoperability and compatibility of elements is of paramount importance. Backward and downward

compatibility and interoperability are crucial because of the long time for adoption of most systems. But upward adaptability (P3I) and consistency with long-run architecture is vital if today's decisions are not to handicap tomorrow's options. In the POM decision-making, technological perspective through time should be maintained. If the burn-in period of a new system approaches its obsolescence time, it would be better to wait for the next system. New technology itself is never a reason for replacement. The technology must promise very significantly better performance without training and logistical burdens before new investment is appropriate, unless the existing system is a "dog." There are always other C3 areas which have more pressing needs than "new and nice to have." Obsolete systems can be assigned to high or low usage units as appropriate to ease transition such as when one system must wait for others or when compatibility requires an entire system to be replaced.

A particularly difficult aspect of resource allocation in C3 is that of combat vulnerability and its tradeoff with field performance. The closer to the combat environment, the more important is the simplicity, ruggedness and short-term reliability of equipment and the need for extremely quick response. These features can be jeopardized by multiple modes of operation for security, anti-jam or low probability of intercept (LPI) protection. However there is also the principle that the forward elements are closer to the enemy and therefore more susceptible to attack, either physically or electronically by jamming exploitation or direction finding (or self-jamming), so these features may be overriding if the information is useful to the enemy.

Similarly the lower in an organization that a system is placed, the more of the systems that will be required by the organization. This implies a larger training plan and higher logistical loads. Thus it is important that systems for use in the company or battalion be very simple, rugged and reliable as well as small and portable. High power, capacity or range are typically not needed in these elements because of their geographic compactness.

Another dimension frequently overlooked is the hierarchical interdependence of problems. What looks like a problem at the battalion level may simply be one at the brigade level that has been pushed down to the battalion. It is almost always easier to solve problems at higher levels than at lower levels where more people are impacted. The only exception is problems at the joint or combined level are often easier to solve at service lower levels because it is difficult to get unity of command or interpretation of the mission at high levels. In the POM environment many decision makers are involved with differing backgrounds regarding the issues. A standardized methodology makes it much easier for those not originally involved to understand the reasoning of the others who have made earlier decisions.

The discussion above should be sufficient to establish that problem formulation for POM C3 resource allocations for the MEB is not an easy matter. What guidance can the MCES give for problem formulation? The most important is to frame the problem (question) in terms of the mission of the force unit not that of C3 itself. More C3 will always serve the interest of C3 but not necessarily of the force. C3 should not get in the way of fighting (or of the training for fighting)! Ideally the question should always be "Can we

show this resource investment is the best way to win the war?", or "How can we kill more enemy with what we've got?" This focuses the question on crucial aspects of using the forces to their fullest potential, not on providing information that may itself not be used. This focus requires ability to identify where critical problems will occur in combat—again a potentially very difficult forecasting problem made easier by combat experience or realistic exercises. But without such assessment it is easy to spend time fixing the accessories or polishing the hood when the engine won't run or is out of gas. Secondly the MCES actively encourages looking at the question broadly. Many times C3 acquisition issues are substitutes for dealing with difficult organizational issues or even training and doctrine problems. Better planning and training are often a better answer to the need for more real-time coordination circuits. A distributed graphic tactical picture is still better than a thousand words, particularly if the local commander can select the picture he wants without being inundated with extraneous information.

The MCES explicitly includes treatment of the dynamics of C3. Problem formulation must take the time dimension into account explicitly. C3 problems are evolutionary, as are their solutions. A history of the problem is important. Requiring a time-phased plan that keeps options open and buys information to take advantage of the options should be part of the problem formulation.

Next the steps in the MCES are illustrated by discussion of applicability to the C3 issues in the POM, keeping the difficulties discussed above in mind.

3. Module 1 Problem Formulation—Precise Problem Statement

It is necessary to limit the scope of this discussion since 1) there are no experts regarding the specific POM issues on the research team and 2) to keep the illustration of the MCES as applied to the POM issues concerning MEB C3 within reasonable limits as an introduction to the later SINCGARS allocation problem. POM decisions are strongly driven by cost and budgetary constraints, changes in perceived threats, politics at all levels, technological feasibility of a great variety of systems, etc., all of which are only tangential to the SINCGARS allocation problem. Therefore discussion will be limited to the question of how to elucidate POM initiatives for their total potential impact on MEB C3.

The Marine Corps has a formal, quantitative process for selection of competing initiatives in the POM. This process is based on the zero-based budgeting requirements of the Carter-era POM process in which initiatives are first priority-ordered and the resulting list is subject to a cutoff based on cumulative budget. The process incorporates a procedure for quantitatively measuring the relative benefit of each initiative. The benefit value for each initiative is then divided by the cost and the ratio is used directly to order the initiatives into a prioritized list. The prioritized list can then be cut off at whatever budget is available. The entire list is subject to review by knowledgeable officers at higher levels and adjustments can be made, but the process is heavily dependent on the strengths of the ordered list and the quantification of the benefit of each of the initiatives. Because of this dependence, the features of the list and quantification are examined in the following paragraphs.

The zero-based budgeting technique of a prioritized list for budget cutoff has two chief strengths. First, it makes quite obvious the truth that all initiatives must compete for funding: that all ten pounds must fit into the five pound budget bag. This truth is often not obvious to the sponsors of competing initiatives, all of which have some merit. It is easier for sponsors to accept that other initiatives are better rather than to be told that their initiatives are not worth their cost. The second strength is the flexibility to respond to fluctuations in the budget cutoff level. This is particularly useful when a number of hierarchical decision processes are involved which make allocation of total budget to the lower levels difficult to make. In this POM process the lower levels can make up their "wish lists" without specific budget targets available.

The weaknesses of the zero-based approach, which have led to its abandonment in most of the government, are also two-fold. It assumes independence of the initiatives and requires a complete ordering of the initiatives when only a fraction of the initiatives will actually need to be compared. These weaknesses are not controlling for the Marine Corps because of the relatively smaller size of the Marine Corps compared to other services.

The strength of the quantification method is that it can be applied when more rigorous measurements are not available. Its weaknesses are in handling multi-dimensional comparisons and multiple decision-making levels. The method is often illustrated by the example of a person without a scale ordering the weight of a set of rocks by comparison only, a task for which the method is well suited. The method is much less valid for initiatives with

many dimensions being evaluated by different groups. Moreover the method generally assumes independence of the initiatives. Unfortunately this assumption reinforces the assumption of independence in the zero-based budgeting procedure and could lead to quite erroneous decisions if the ordered lists are not thoroughly examined after the budget cutoff to make sure that no essential elements are left out of the budget. This gross error can be avoided by inspection and reinsertion of those initiatives below the cutoff that are essential to those remaining within the budget cutoff. However it is much more difficult to similarly correct the uni-dimensionality of the method, particularly when combined with the zero-based budgeting approach. Since the method orders on the basis of overall benefit, it may over-emphasize one mission, geographic area, function or any other subdivision of the total Marine Corps effort. The division of the benefit by cost for priority ordering means that a particular subdivision may dominate the list simply because it is cheaper to fix that particular problem. The method leads away from a balanced POM particularly when reinforced by the zero-based budgeting approach and especially during sizeable budget cuts. This effect can be alleviated by placing large amounts of the budget in a balanced "core" that is not prioritized, but this fix becomes less effective as the core becomes larger but budget cuts affect more initiatives. This can be seen in the extreme: if only a few initiatives could be afforded, they almost certainly will not be well-balanced if only ordered by the quantification method.

It is assumed that the Marine Corps feels that the current POM process is acceptable. What are the features of the MCES that might offset the

weaknesses of zero-based budgeting combined with the quantification method? The major danger is that an unbalanced or incomplete POM can result from interdependencies of the initiatives which are not addressed in the methodology. To avoid this, MCES provides a means of subdividing the POM into major missions or other areas affected by the initiatives. Moreover MCES provides a means of looking beyond overall benefit of initiatives to the specific contributions of each initiative to these missions. Even without a complete quantification analysis it identifies interrelationships and appropriate measures. Finally it gives an indication of what effort would have to be expended to quantitatively show that an initiative is actually cost-effective. This alone may lead to more realistic assessments by sponsors.

4. Module 2—System Bounding

The purpose of system bounding is to explicitly define the physical scope of the problem. The outputs are lists or tables of the physical elements and structures that enumerate the levels of the problems. Because of the illustrative nature of this case and the breadth of MEB C3, the lists will not be comprehensive or in the detail that will be provided in the SINCGARS allocation problem.

The *system* of focus is the MEB C3. The conceptual name for this is the Marine Corps Tactical Command and Control System (MTACCS). It consists of the people and the hardware and software systems in the operational headquarters or facilities (C2FACs) of the MEB. The generic C2FACs are listed as Table 4. There are subsystems of the MTACCS for ground C3, aviation C3, combat service support (CSS) C3, and intelligence. Table 5 shows some of the major third level systems under each of these. Some of these are currently

under development while others are in place. The communications elements are represented in the Marine Corps Tactical Communications Architecture overview chart which cannot be reproduced at this scale but which should be familiar to anyone involved in the POM C3 discussions.

TABLE 4. GENERIC C2 FACS (SELECTED)

A. COMMAND ELEMENT (CE)
   1. COMBAT OPERATIONS CENTER (COC
   2. INTELLIGENCE CENTER (IC)
   3. SIGINT/EW COORDINATION CENTER (S/EWCC)
   4. TACTICAL LOGISTICS GROUP (TACLOG)
   5. SYSTEMS CONTROL TECH CONTROL (TECHCON)
   6. REAR ARE OPERATIONS CENTER (RAOC)
B. GROUND COMBAT ELEMENT
   1. COMBAT OPERATIONS CENTER (COC)
   2. INTELL CENTER (IN)
   3. FIRE SUPPORT COORDINATION CENTER (FSCC)
   4. ARTILLERY FIRE DIRECTION CENTER (ARTY FDC)
   5. FORWARD OBSERVER (FO)
   6. COMMAND POST (CP)
C. AVIATION COMBAT ELEMENT
   1. TACTICAL AIR COMMAND CENTER/DIRECTION CENTER (TACC/SADC)
   2. TACTICAL AIR OPERATIONS CENTER/EARLY WARNING (TACC/SADC)
   3. DIRECT AIR SUPPORT CENTER (DASC)
D. COMBAT SERVICE SUPPORT ELEMENT

The elements above are related by certain structures, in MCES terms. The primary well-defined structures are the command structure of the MEB shown in Figure 10 by the C2FACS and the radio guard chart or the network

structure which is shown in the MCTCA overview chart. These provide the authority and conceptual connectivity for C3. Another well-defined structure is that of the Marine Tactical Systems Message Text documents (MTS-MTF) which define the information that flows within the networks in Volume IV of the TPID. Apart from these hard copy messages, much of the specialized computer to computer data flows in accordance with message series defined by Tactical Automated Data Information Links (TADIL). This is part of the interoperability structure which is available as needline tables of C2FAC interconnection such as shown in the tables of the Marine Corps Tactical Communications Architecture (MCTCA). Less well-defined structures are the doctrine and standard operating procedures that are completely or partially in place for existing and future systems. Access to data concerning the detailed parameters of these systems and the structures in which they are implemented is needed to make choices in the POM on MEB C3 issues. The data however should be selectively organized to support the later modules of the MCES or it can become overwhelming. In practice much of this less well-defined data is available only in the minds of experienced personnel.

TABLE 5. MTACCS SYSTEM AND ILLUSTRATIVE SECOND AND THIRD LEVEL SYSTEMS

Ground C2 System (Second Level)
- Tactical Combat Operations (TCO) (Third Level)
- Fireflex System (Third Level)

Aviation C2 System (Second Level)
- Advanced Tactical Air Command and Control Central (ATACC)
- Tactical Air Operations Module (TAOM)

Combat Service Support System (Second Level)
Marine Integrated Personnel System (MIPS)
Logistics Automated Information System (LOGISTATS)

Intelligence System (Second Level)
Technical Control and Analysis Center (TAC)
Tactical Electronic Reconnaissance Process and Evaluation System (TERPES)

The forces supported by the MTACCS are those of the MEB and the naval or joint forces that are supporting the MEB. Again, this includes the complete force units with ground, air, and CSS elements, not merely their C3 in the C2FACs. Understanding of the missions and capabilities of the forces is important for predicting the payoff of C3 initiatives if measures of force effectiveness (MOFEs) are used for assessment, as is most desirable. Within the POM process this is largely left to the operational experience of the participants.

The *environment* of the C3 system and the forces controlled includes the physical environment (terrain, geography, weather), the threat, supporting command structures including higher level commands and intelligence agencies, as well as medical, training and other support structures for the MEB outside of the CSS unit and finally the theatre and national level communications systems. The diverse and rapidly changing environment of the MEB means that a variety of systems report the intelligence, meteorological, positional, navigational, and identification status of its elements.

The *rest of the world* which does not affect the issues at hand is assumed here to be everything not enumerated above. In reality, as mentioned at the

beginning, many doctrinal, technical, and political issues affect the POM decisions. Clearly those must be identified on an ad hoc basis.

5. Module 3—C3 Process Definitions

The C3 process consists of the functions that must be performed by the C3 system to coordinate forces in the planning and execution of their mission. The MCES breaks the process into functions of sense, assess, generate, select, plan and direct. The Marine Corps has a set of activities called Marine Corps Basic Operational Tasks (MBOTs) which describe in detail the tasks of the C2FACs in conducting, planning and executing the missions such as fire control. These tasks are defined primarily in terms of messages that must be passed between the generic C2FACs of the Marine Corps Tactical Command and Control System mentioned above. These tasks are more detailed than appropriate for some POM C3 issues but many of the participants would be familiar with them from experience. The overall MBOT structure provides the basis for more detailed analysis on major issues which are consistent with quantitative modeling. This will be described in the SINCGARS application. In lieu of a detailed study such as for SINCGARS, the MCES functions provide a mental checklist for evaluating the completeness, balance and interoperability interfaces of any C3 initiative being applied to the MEB missions.

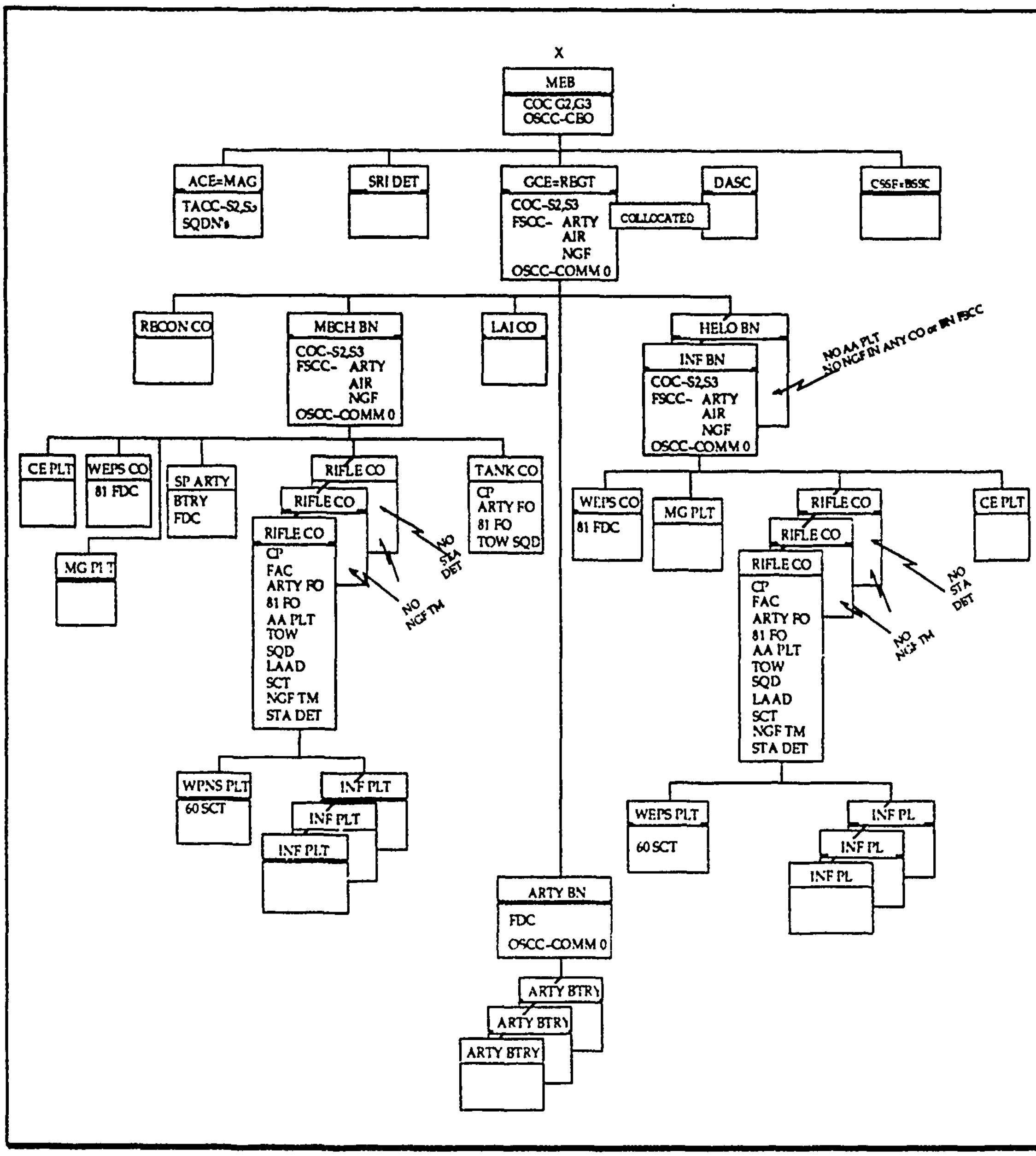

Figure 10. Organization Chart

6. Module 4—Integration of System Elements and Functions

This step identifies the interrelationship of the elements and structures found in Step 2, system bounding, with the processes of Step 3. The result is an architecture which assigns function to element. The Marine Corps has an

architectural concept for C3 in the C2 Master Plan. Based on 1987 C2 plan, it consists of the Landing Force Integrated Communications System (LFICS) Architecture, the Marine Corps Communications, Navigation, Identification (CNI) architecture and the Marine Corps Command, Control, Communication and Computer (C4) System Architecture Capstone. These architectures come together in the Marine Corps Basic Operational Tasks (MBOTs) which designates activities for C2FACS and force units which were identified in Step 3.

The C2FAC MBOTs however can be the though of as procedures for members of an orchestra to play their individual instruments. A score or scenario and a conductor or commander must be added to hear a symphony. The symphony can be heard in the mind of POM C3 decision makers based on their experience, or can be approximated by some exercise, test or simulation if time is available. Usually the results of small scale tests or simulations are available but it is up to the POM decision makers to extrapolate to the effect on the whole orchestra playing various scenarios. Part of the difficulty in POM decisions that explains variations in the decision makers views is predicting the degree of skill which the players will reach with new instruments or new scenarios which may call for changes in training, doctrine or MBOTs. Reports of developmental and operational testing should be available for POM decisions on C3 acquisitions but those tests are usually focused at the operator level rather than on the performance at MOE or MOFE level which would be more relevant for POM level decisions on priority, number and timing of systems to be acquired.

The Marine Corps is already moving from manual, unsecure voice, analogue radio-telephone tactical C3 to a significantly automated, computerized, digital, secure telecommunications system. This requires that the assignment of function to element (who does what) which is the foundation of any architecture must become *less* flexible and *more* well defined because the hardware and software replaces manual flexibility with techr ically determined interfaces which must be compatible. The architecture must specify standards for these interfaces or specialized functions will become isolated even as they become more capable. Conformance with defined architectures must be a criterion for evaluation of initiatives in the POM process. MCES analyses of module 4 can identify important interfaces that are not obvious when considered only as communications or ADP systems.

7. Module 5—Specification of Measures

This module identifies what are the relevant MOPs, MOEs and or MOFEs for decision making for an issue. The MCES emphasizes the importance of MOFs and MOFEs. The Marine Corps apparently has no existing guidance with regard to this module. Measures can be classified in several different ways, for example quantitative vice subjective. Either may be appropriate in the POM C3 decisions, but as more detailed analyses are performed, quantitative measures are emphasized. For example, measures change from only relative or categorical to those having precise physical units.

In general, measures relate either to performance; how well the system does its job, or to vulnerability; how reliably it performs under stressed conditions. Often high perfcrmance systems also have higher vulnerability

partly because of the necessity of centralization or simply through error by a specialized operator, which cannot be diagnosed or fixed by anyone else.

Twenty years ago, the TRI-TAC joint communications organization, later to become the Joint Tactical C3 Agency, identified 6 specific measures of performance and vulnerability effectiveness which have become standards for communication. The TRI-TAC measures were shown in Table 1. Performance includes measures of timeliness, quality, efficiency, and convenience within a communications context. For example timeliness measures include speed of service and call placement time. The quality of service is measured by grade of service and information quality (intelligibility) as well as lost message rate and intercept rate. Efficiency is measured by spectrum utilization and ease of transition and interoperability. Convenience includes transportability, mobility and ease of reconfiguration. Vulnerability is measured by survivability against destruction and against jamming and availability. Fairly precise definitions were made by TRI-TAC for each of these measures. Note that they are largely (with the exception of survivability) scenario independent i.e. they can be determined from tests of the equipments in laboratory environments. They are therefore generally MOPs by the MCES hierarchical definition of equipment parameters, MOPs, MOEs and MOFEs. The TRI-TAC measures are probably not of high enough level for assessment of most POM C3 issues although they may be useful in comparing alternative communications systems and for identifying interoperability. Survivability if measured on a system level, is also appropriate.

As noted above, POM C3 issues are now being dealt with by establishing relative benefit without specifications of MOEs or MOFEs and with particular attention to benefit-costs ratio. In a group decision making such as the POM, detailed discussion and debate on lower level measures of performance, MOPs or even equipment parameters, can preclude the more important discussions of higher level measures, MOEs and MOFEs. Lower level measures should of course be accurate but since they are often unknown or vary with scenario, it can be useful to focus discussion on only the critical MOPs as determined by review of higher level MOEs and their relationship to the MOPs. This contrasts with simply identifying differences in the lower level measures as is often the focus in POM discussions. MCES can help raise the sights of the POM C3 issue discussions to higher level measures even when the discussions must be qualitative. In comparison to the current approach, MCES leaves a traceability of why one system was considered to be better than another.

8. Module 6—Generation of Output

The purpose of this module is to combined the results of module 4, the architecture, (the relationships of the elements and processes) with techniques for generating the values of the measures chosen in module 5. For most POM issues, where qualitative MOEs are to be evaluated by judgmental or group decision making, the specific architecture may be assessed directly by the individuals using qualitative categorical or relative scoring. Often these assessment are based only on equipment parameters. When more time is available, or when choices between quite different systems, a model, test or exercise may be set up to provide quantitative values

of the higher level measures. The model may be a detailed computer simulation of the C3 functions as performed by the elements. Ideally this model of the C3 system will serve as the decision making portion of a combat model or can be interfaced to an existing combat model so that MOFEs can be obtained. Both tests and models to POM issues are discussed briefly below.

The results of tests and exercises are particularly appropriate for both direct assessment of alternatives or for validation of the model. Validated models can then examine more scenarios than are possible in field tests. In the POM decisions tests and exercises will have great impact but again experienced extrapolation of test results will be necessary unless a model is available.

Conducting tests requires that prototype or qualified systems are available and that detailed training and doctrine have been adjusted to the new system. Usually, this comes too late for many of the POM C3 issues. Therefore models of varying complexity and validity are often used to produce values for measures. Models require great amounts of data concerning the bounded elements and the functions. Often much of the input structure and process is undocumented except in the minds of experienced personnel. The MCES can provide a template for determining whether a model was appropriately matched to the issue. By identifying the important measures, MCES establishes whether the outputs of the model were appropriate for the decision. By establishing the elements and functions, it can indicate whether the model had the right input data. Even simply bounding the system indicates whether the models scope and depth were well matched to the problem.

The documentation of 1) the assumed scenario and architecture, 2) the relationship and the approximations in the model, 3) the input data for equipment parameters, environment, 4) any verification and/or validation is very important to the credibility of the results for POM decisions. Often considerable efforts at measurement both in testing and modeling are deemed not credible by experienced decision makers. Following the MCES can help avoid such waste of time and expenditure.

Even a well-documented model may generate non-credible results without an appropriate experimental design which can establish the statistical validity of the model under varying environments. Appropriate designs for large-scale simulations require considerable time in both planning and execution. Because of the importance of the man-machine interface to C3 systems and the difficulty of modeling human decision-making, C3 models, as opposed to communication models, often call upon humans as elements. These models are actually gaming systems. Thorough training of appropriate human operators is particularly important in the testing of C3 systems with games. Credibility depends upon the experience of the games and can be enhanced by having the decision makers participate as in the Navy POM games at Newport. Following the MCES provides a checklist to ensure that the preparation of such a game is complete and that worthwhile answers will be obtained. What is tracked is the overall relative benefit of the initiative compared to others.

9. Module 7—Aggregation

Usually a number of measures with values will have been identified by application of the MCES modules above. These measures must be aggregated

to the highest degree possible so that the original question can be answered. This includes an assessment of the credibility and sensitivity of the results.

In the case of the POM process, there are many issues being considered simultaneously and most issues have inter-relationships with other systems and issues. This makes for particularly complex decision making. One reason for group POM decision making is to take advantage of the knowledge of many individuals in identifying and keeping track of the interrelationships. In the group decision making it is possible to keep track and aggregate dollar costs across initiatives and years. There is currently no organized means of tracking or aggregating measures of performance, effectiveness or force effectiveness by mission or function nor the many interfaces between systems. It may be possible to apply the MCES to standardize formulation of POM C3 issues, to track interfaces and to aggregate measures of effectiveness. The Table 1 shown earlier reflects one mechanism for accomplishing this.

With regard to measures of effectiveness, using MCES may make it possible to indicate the extent to which major force units are supported by C3 processes and systems. For example in air operations C3, the sense, assess, generate, select, plan and direct cycle can be aggregated in timelines. A time window for planning and targeting that would permit full sortie rates and accurate ordnance delivered on target by Harriers or other aircraft could be established and compared to current performance. The potential reduction from current time could come from sensors, computers, planning aids or communications. Thus each different system is compared on one MOE. This

approach has been used in Air Command and Control System planning in NATO's air defense system.

In summary, the MCES, although not devised for a POM decision-making environment, could provide standardized information on the interrelationships of C3 initiatives that would compensate for some of the methodological weaknesses of the current Marine Corps POM decision-making.

TASK 1B MCES ANALYSIS OF SINCGARS ALLOCATION

A. INTRODUCTION

The Marine Corps plans to purchase over 12,000 frequency hopping VHF SINCGARS radios of six different configurations. Half (6000) of these are the man pack PRC-119 which will replace the existing PRC-77 and half are the vehicular VRC-88 to 92 models which replace the VRC-12. They will be phased in over about six years so there will be a long period when the frequency hopping radio and the single channel PRC-77 and VRC-12 radios must coexist. This raises a question of allocation of the new SINCGARS within the Marine Corps. The final allocation will depend upon many logistical and training factors but a primary factor should be the potential operational impact in combat. The Warfighting Center has asked NPS for an analytical tool to address the relative effectiveness of alternative SINCGARS allocations. Such a tool could potentially serve for architectural evaluation for other new systems as well.

The NPS approach was to define the problem following the Modular Command and Control Evaluation Structure (MCES) and to model the alternative network architectures with a flexible object-oriented simulation written in the MODSIM language. Linking these two stages requires a quantitative measure of C3 effectiveness. The development of the measure of effectiveness is outlined in this document and a table of relative performance values (penalties) for application of the measure is presented for review by the Warfighting Center. Described in detail below, the quantitative

measure of C3 effectiveness to be produced by the model will be the total penalty-weighted time late of VHF messages. These messages are directly linked to the C3 activities of the MAGTF by a scenario-independent set of doctrinal tasks performed by Marine Corps C2 elements known as C2FACS. With this measure and the simulation model, analyses can readily be performed to test the robustness of any radio allocation to varying the rate of tasks and the resulting increased message flow.

B. MCES

Module 1: Problem Formulation for SINCGARS allocation

The Marine Corps Tactical Command and Control System (MTACCS) concept expresses the requirement for rapid, reliable, secure, jam-resistant mobile voice and data communications. These requirements are met by SINCGARS, which has high capacity, promises a ten-to-one improvement in MTBF, has built-in encryption, is virtually jam-proof, is light and can carry either voice or data. Eventually SINCGARS may replace all existing VHF single-channel net radios on a one-for-one basis. But during the long changeover, there may be need (in fact there has been need!) for combat operations by Marine Expeditionary Forces (MEFs). SINCGARS is downward compatible by operation in a non-hopping mode. However it thereby loses its protection against enemy jamming and exploitation by direction finding. Therefore it is likely that operational communications planners would in general create separate nets for SINCGARS and for the older radios. If so, the allocation decision can be thought of as the assignment of available SINCGARS to the nets that most need a reliable, secure, jam-resistant capacity to process the traffic it will encounter. Since the older radios can be secured by

existing VINSON cryptos, the security issue will not be further addressed here.

The problem then can be stated as: What assignment of available SINCGARS to doctrinal nets will provide the most combat effective communications? Our current understanding is that the SINCGARS will become available at approximately 1000 per year with the earliest deliveries to the materiel and training establishments in order to complete testing and fill the maintenance and training pipelines. Once these pipelines are filled, the assignment can be responsive to the potential workload and threat in potential combat.

Module 2: System Bounding

This module identifies the environment of SINCGARS and the elements with which it must interact. The SINCGARS is a convenient, general purpose, VHF communications equipment which may appear in almost any of the C2 facilities (C2FACS) of the Marine Corps. Most of the current VHF single-channel capability is in the VRC-12 and PRC-77 radios so these are also relevant portions of the total communications system to be examined. It is assumed that any changes to the UHF, HF and multi-channel communications networks will not affect the the VHF equipments. Connectivity to non-Marine Corps units is not addressed because at the tactical level of the MEB this would be rare.

An important MTACCS change is the planned increase in digital data traffic from increased automation of the other systems of the MTACCS such as TCO. SINCGARS has a data capability up to 16 kilobits/sec., which is compatible with current Marine Corps terminals. The current data terminal

most likely to be used with SINCGARS is the hand-held Digital Communications Terminal (DCT) which is very slow. Robustness to increased data traffic must be considered. The "Green Machine" the Marine Corps ruggedized IBM-compatible personal computer is being replaced with the AN/UYK 83 and 85 which also have compatible data rates.

An important limitation of SINCGARS is the co-siting problem both with itself and with other VHF radios. The mutual interference limits the ability to have two SINCGARS operating antennas within several hundred feet. Remoting of antennas is required for large C2FACs.

The other aspects of the physical environment of SINCGARS may be very severe but, there is no reason to believe SINCGARS will have less ruggedness than the current radios. SINCGARS is designed to Electro Magnetic Pulse (EMP) hardness standards but only conventional combat will be considered here.

SINCGARS is considered to be invulnerable to enemy jamming and direction finding. The enemy threat to current VHF radios can be severe. In particular mobile receivers near the front line may easily be jammed since mobile antennas are not directional and terrain shielding is limited in most mobile operations. Direction finding is a threat against fixed VHF radio but is more likely to be used again the UHF and HF radios of more static higher headquarters and will not be considered further here.

The major subsystems of the SINCGARS are the power supply, receiver-transmitter, vehicular adapter-amplifier, high power amplifier for long-range models, and antennas. The appropriate components are specified to be acquired with models VRC 89-92 and the PRC-119. This study will not

distinguish between these models since it is not known in general which model the particular C2FAC will prefer. As noted above about half of the SINCGARS are planned to be manpack and half are vehicular, which should allow sufficient flexibility. Also, more than 10% are planned to have a retransmission capability by the addition of a second power amplifier and retransmission cable.

The SINCGARS will be compatible with NATO single channel VHF-FM radios as well as existing Marine Corps radios of the PRC 25/77 and VRC 12 family (VRC 12/43/45/46/47/49/53/64 and GRC 125/160). The SINCGARS will also be compatible with the airborne ARC-210 for ground/air coordination. Aviation use of SINCGARS for air/ground coordination will receive limited attention in this study since only a very small number of SINCGARS are destined for aviation use. The SINCGARS will be utilized and supported in accordance with Communications Electronics Operating Instruction (CEOI). Generally they will be operated by specially trained members of the C2FACs. The operational concept is that of self-use rather than requiring a full-time operational specialist. Organizational maintenance at first and second echelons is to be performed by the unit. This is primarily battery replacement because of the long MTBF (over 1000 hours) and very short MTTR (goal of 15 minutes at organizational level). The elements of the SINCGARS allocation problem are sketched in the onion diagram in Figure 11.

Module 3: C3 Process Definition for SINCGARS Allocation

In this module the functions performed with the SINCGARS are identified. The five Marine Corps mission areas are air operations, ground

operations, intelligence, fire support and combat service support. The MAGTF Interoperability Requirements Concepts (MIRC) contains the interface tasks performed in the Marine Corps which are similar to to the MCES standard functions of sense, assess, generate, plan and direct.

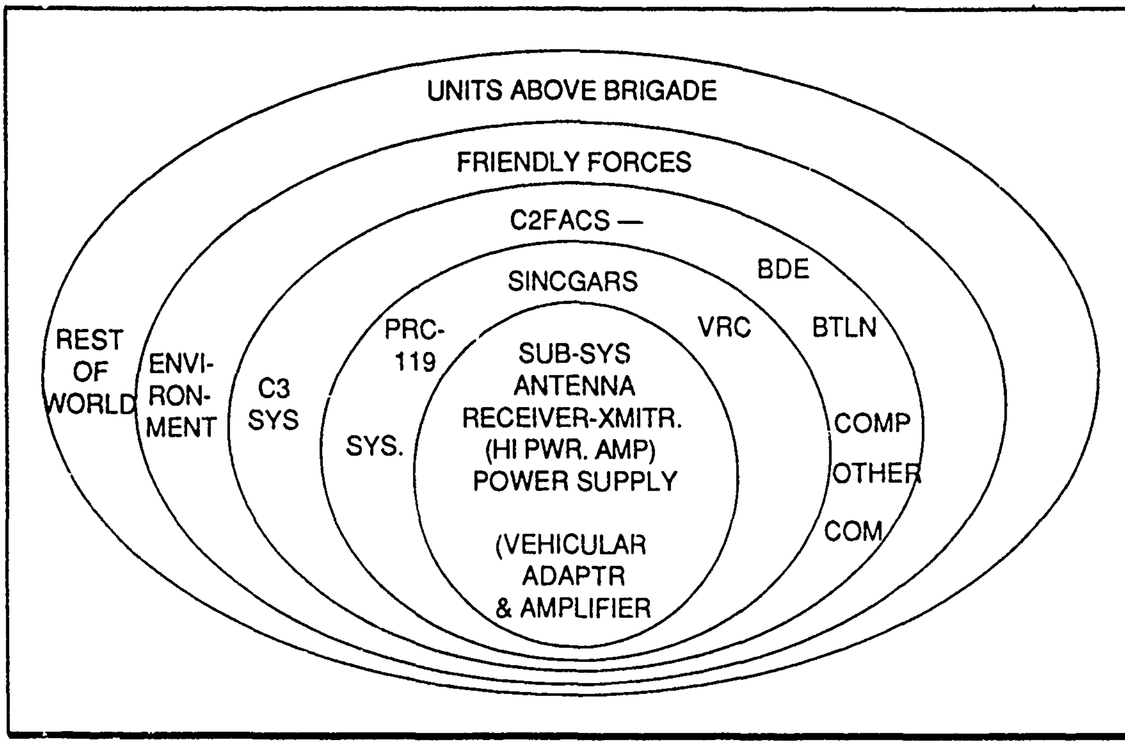

Figure 11. Onion Diagram of SINCGARS Allocation Problem

Each of these functions is performed by a subset of the C2FACS in a sequential fashion to accomplish the five missions. To capture these sequences the Marine Corps Technical Interface Design Plan for Marine Tactical Systems (MTS-TIDP) in its Volume II entitled Multiple Agency Message Exchange Sequences (MAMES) defines a three levels of functions. At the top level for each of the five mission areas are Marine Broad Operations Tasks (MBOTS) such as artillery call for fire in the fire support mission. Each MBOT is then subdivided, for example standard fire mission,

check fire etc. These subdivisions are called Broad Operational Subtasks (BOSTs). Each BOST is further subdivided into Message Exchange Occurrences (MEOs). Each MEO explicitly identifies the origin and destination C2FAC, the type of message sent and the net used for each MEO in accomplishing the BOST. In addition, each MEO cross-references the interface task which created it and the next interface task which its receipt supports. The normal sequence of the MEOs is roughly indicated for each BOST. There are as many as 50 MEOs for a BOST.

For purposes of this module it is sufficient to note that the BOSTs and MEOs fully represent the tactical communication needs of the doctrinal C3 functions of the Marine Corps. The volumes of the TIDP contain a structured representation of the required information flow in tactical operations since Volume III is the Message Element Dictionary (MED) or data dictionary, Volume IV is a Message Standard (MS) and Volume V is a Protocol Standard (PS). Together these provide most of the information needed to complete a simulation model of tactical communications in the Marine Corps, as will be discussed in further modules. The only weakness of the MTS-TIDP is that specific decisions required by the tasks are not identified, therefore the absence of information or information quality can't be assessed in terms of task quality. The execution of the MEOs, the BOSTs, and the MBOTs can be addressed on the basis of their completion and how long they take, but not on their quality from this data base, which is the most detailed functional requirement we have been able to obtain.

Module 4: Integration of Elements and Functions

In this module the C2FACs and the BOSTs are integrated into a conceptual model of the VHF tactical communications networks. As noted above this is possible because of the detailed definitional structure represented in the MIRC and TIDP. The TIDP is implemented in a relational data base which makes it possible to sort virtually any of the MEO information into the structure required. For example Tab A of Volume II at the TIDP lists the interface tasks and their C2FACs whereas Tab B of Volume II sorts the C2FACs and lists their tasks.

Appendix A to this report lists SINCGARS C2FACs for the proposed analysis. Appendix B lists the nets for the analysis of VHF-FM single channel radio use has been added for review by the War Fighting Center for appropriateness. The designation was made by reviewing each MEO to determine whether it was a candidate for potential SINCGARS use. This was designated if the net was specified in the TDP as VHF as opposed to HF, UHF or MUX. Where several nets including VHF were specified, judgment of the substitutability of each SINCGARS engagement was made. Appendix C lists the potential SINCGARS nets of each C2FAC. This table allows judgement to be made of the potential number of SINCGARS radios at each C2FAC. This number can later be deduced given that a net has been selected for a SINCGARS allocation.

Additionally designation of potential SINCGARS use in each MBOT and BOST has been made for validation by the War Fighting Center. This appears in Appendix D. The designation was based on the same process as above.

With the information above, a crosswalk can be made from task or C2FAC to SINCGARS net and vice versa. Additional information needed to change the conceptual model to a quantitative includes estimating how often the tasks must be performed or at least the relative frequency of the tasks. This information was pursued but no definitive data were found. A judgmental estimate can be made but a documented source cannot be found. These rates drive the traffic load of the communications architecture.

The general architecture of VHF tactical communications has now been established. Specific candidates of SINCGARS allocation to be evaluated can be created by choosing nets based on estimates by planners or by general principles such as giving SINCGARS to nets where traffic is anticipated to be high or which serve units which will be in position to be jammed. The conceptual model above identifies how many of these nets can be supported by a given number of SINCGARS. It remains to be shown how to measure the relative C3 effectiveness of alternative allocations of SINCGARS after the candidates are subjected to traffic load.

Module 5: Specification of Measures for SINCGARS Allocation

In this module a set of quantitative measures for assessing alternative allocations of SINCGARS to nets will be proposed. Measures of effectiveness can be categorized by level (MOP, MOE or MOFE) or by categories such as performance (how well the system does its job) and vulnerability (how reliably it does the job under fire). Both of these dimensions will be discussed below.

The highest and generally most desirable measures are those of force effectiveness (MOFEs); MOFEs measure combat results for different

alternatives. This is the final mission payoff, but it is often very difficult to estimate how well a MAGTF would perform with different C3 systems. In fact a well-trained MAGTF might fight just about as well with any C3 system if given enough time to adapt its doctrine, training, personnel and procedures to that system. It takes a major step forward in C3 to have a significant improvement in MAGTF fighting performance. SINCGARS might be such a step forward if the scenario was an assault operation against a fully-alerted opponent heavily jamming with airborne or RPV jammers targeted against time-critical Marine Corps operations. It might be possible to develop such a scenario and a combat model to support it but none exists at this time to our knowledge. Even if it did, it might be argued that such scenario-dependence is not desirable in establishing SINCGARS allocations because of the need to train for many contingencies.

The Warfighting Center gave NPS guidance that although some scenario-dependence may be inescapable, it should be minimized in light of today's changing circumstances. Therefore it may be more appropriate to step down to measures of C3 effectiveness (MOEs) rather than MOFEs, keeping in mind the MAGTF combat mission to the highest extent possible. C3 MOEs measure how well the C3 system does its job and/or how reliably. The SINCGARS, as a tactical communications equipment, contributes to C3 in the dissemination of information and orders. The MBOTs, BOSTs and MEOs follow directly from the five mission areas and identify specifically which messages must flow in sequence to perform the C3 tasks. Thus a measure of how quickly and reliably the SINCGARS executes the MEO message flows can directly measure the Marine Corps' tactical communications effectiveness. The effect of

changing scenario can be introduced by escalating to higher rates (with fixed relative frequency). This would represent more difficult workloads and more capable enemies.

A subjective allocation of SINCGARS could be made without a quantitative computational model at this stage simply by asking experienced officers to review the BOSTs and allocate the available SINCGARS to the VHF networks that are most important (highest traffic and most vulnerability). However, even experienced officers might have difficulty deciding the tradeoff of traffic and vulnerability and thinking through how the various nets would actually perform in each case. This is why a quantitative model such as discussed in the next module is desirable.

The discussion above leaves open how the performance and vulnerability would be measured in the quantified model. The performance of a communications system can often be measured at the MOP level by counting number of voice channels or number of bits/second. SINCGARS as a single-channel voice radio does not offer major improvement over the PRC 77 or VRC-12 in a benign environment. As a data communications device it is superior. With a mix of voice and data traffic it is more difficult to assess SINCGARS at the MOP level. Therefore a higher level measure (MOE) is desirable. A C3 MOE that can be compared across communications, processing and sensing is timeliness. Timeliness is closely related to combat effectiveness if a time window exists for an operation i.e. if it is time critical. In the single-channel radio nets timeliness, time to complete transmissions would be such an MOE. Timeliness in this sense is a function of traffic workload.

Traffic workload can be obtained for a BOST from the MEOs as follows. The length of each message can be calculated in bits for data or seconds for voice (approximately). If relative frequency of the BOSTs can be estimated, the traffic load on each net can be calculated, since the sequence of messages (MOEs) is also known. As usual there may be transient delays even when total capacity is larger than the workload. These transient delays could be serious in fire support nets, during an attack for example. The total time late measures this impact. Jamming would overload unjammed nets and result in less timely completion of BOSTs.

The various missions may have varying sensitivity to timeliness. This variability could be reflected by accumulating different penalties for each second of time delay depending on mission. The penalty would be sized to the relative importance of the time delay. The same penalties could be assessed for any delay on a specific net or could be different for each BOST or even for each MEO, since different messages and BOSTs are often transmitted on the same net. Assessing delay penalty at the level of MEO seems too low since a MEO is part of a BOST and does not represent completion of an activity. In other words, a partial BOST (MEO) doesn't accomplish anything. A penalty for each BOST seems most appropriate since a BOST represents a complete military task relevant to a mission area. Therefore time penalties will be assessed for each BOST. The total penalty-weighted time delay on the networks would be a satisfactory performance measure of how well the single channel VHF radios perform the C3 mission. An initial set of relative penalties are shown in Appendix D for each BOST.

The reliability aspect of the candidate architectures can be included in timeliness. Reliability can be separated into inherent failure (MTBF and MTTR), failure under attack (jamming or destruction) and operator failure (user friendliness). These failures are quite different but can all be represented by increased time delay to allow for repair or replacement, jamming work around, or operator entry and restart. Some of these failures would require additional input data concerning field conditions which are not yet available for SINCGARS. However inherent failure and jamming can be estimated and net entry time can be parametrically represented.

Module 6: Generation of Output Data

In this module a quantitative model is presented that would generate the penalized time delay on the single-channel nets. It is an object-oriented simulation written in the MODSIM language which can easily be manipulated to provide the values desired. The model developed has four fundamental object types, units, radios, nets, and the traffic generation object. In this section, we provide the salient detail of the model by describing the properties of these four object types. The unit object type is the base type from which all of the MAGTF units are derived. Instances of unit objects range from a platoon object (≈ 30 men) to a division object (≈ 15,000 men). The communications equipment owned by a unit is housed in a radio array. Each radio is, in turn, connected to a radio net. The differences between unit types are the composition of the radio array and the rate of BOST initiation for each type of BOST, and the net membership of the radios owned by the unit.

Each unit is stimulated by the traffic generator by having a stream of BOST initiations sent to it. The unit then determines the first MEO of the

BOST to pursue, finds all of the receivers which must receive the MEO, and submits the MEO for transmission on all of the nets required to reach the receivers. There are circumstances under which the unit will not be able to reach some of the intended receivers on the net specified by BOST. Thus, the unit contains a complex routing mechanism which determines the sequence of units who will relay the BOST to the intended receiver.

Each BOST is being pursued via the execution of MEOs between units. After a unit is a receiver of an MEO, it consults the BOST to determine the next MEO. It determines the appropriate net using its routing mechanism, then submits this new MEO to the appropriate set of radios, one radio per radio net. The radio acts as a prioritized queue of MEOs, as well as possibly initiating busy periods of the attached radio net. In order to test the value of a specific C^3 architecture, the system must be stressed in a realistic fashion independent of a specific scenario. The use of the MBOT/BOST/MEO framework was briefly described above.

An example of an MBOT in *air operations* is ***Artillery** Call for Fire,* with the constituent BOST *Standard Call for Fire.* This BOST might be initiated by a Battery Forward Observer (BTRY FO). It involves the cooperation of the Artillery Battalion Fire Direction Center (BN FDC), the Infantry Battalion Fire Support Coordination Center (BN FSCC), and the Artillery Battery Fire Direction Center (ARTY BTRY FDC). The MEOs which are required to complete the *Standard Call for Fire* include the original call for fire, the clearing of the fire mission up the chain of command (optional), and the relaying of the clearance back down the chain (optional), the spotting and firing directions exchanged between the BTRY FO and BTRY ARTY FDC, the

end of mission and surveillance messages. There is some concurrency of MEOs in this mission, as well as a simple precedence structure between MEOs.

Each of these actions is identified as a *Task* attached to one of the *Message Exchanges* within the MEO. Each specified message has associated with it a message format with the content identified message sender, receiver, radio net to be used, and duration. Some *Tasks* are pursued concurrently, while some have precedence over others.

To generate traffic for the MAGTF tactical communications system, a sequence of BOSTs occurs at each unit. These BOSTs generate the specified MEO with the associated message traffic requirements and sequence.

Each unit, j, in the MAGTF has an assumed rate of occurrence for each BOST, i, given as λ_{ij} if it is an initiator of that BOST. Our traffic generation scheme must produce BOST initiations at each of the initiating units at the specified relative rates.

For efficiency and centralization of control, we will generate BOSTs in a central process:

```
while (not TIME'S UP)
    sample DELAY with mean = 1/λ
    wait DELAY
    choose a BOST and UNIT
    tell UNIT to INITIATE_BOST
end while
```

Algorithm 1. MODSIM Code for the BOST Generation Process

where $\lambda = \Sigma_{(i,j)}\lambda_{i,j}$. Given BOST i and unit j, the BOST-unit combination (i,j) is chosen with probability λ_{ij}/λ. If the delays are chosen to be exponential, then each BOST-unit initiation is a filtered Poisson process. Otherwise, each time between BOST-unit initiations is a sum of a geometric number of independent identically distributed delays.

Radio net transmission time is the only limited resource in the model. A net may be thought of as a one-talker-at-a-time party line. Units connected to the net, called subscribers, all can receive every message transmitted on the net, while only one subscriber may transmit at any time.

The nets in our model use a highest-priority-first message discipline, which may be slightly more orderly than the real system. When an opportunity for transmission takes place, the net polls each of the subscribers and chooses a unit with a highest-priority message at random. With penalties such as Appendix D for each BOST, a penalty weighted total delay can be computed for any allocation of SINCGARS to the nets.

The model must be exercised within an experimental design in order to provide statistically significant results. The experimental design will examine alternative allocations of SINCGARS to various nets). The allocations of SINCGARS to nets will be varied and the penalty-weighted time late accumulated with and without jamming. The model may also examine the effect of changes in the relative frequencies of the BOSTs and of values of the penalties to determine sensitivity to these subjective inputs.

Module 7: Aggregation and Interpretation

In this module the results of the model in terms of penalized delay will be displayed and integrated into recommendations for the Marine Corps with

regard to allocation of SINCGARS during the transition to an all-SINCGARS VHF single-channel capability. A discussion of the possible extension of the model to other issues will be given.

The nature of the conclusions will be that certain nets are less robust for increased intensity or rate of BOSTs than others under jamming and should therefore be allocated SINCGARs when available. It is anticipated that this behavior will not be sensitive to the absolute number of SINCGARS available, but as more SINCGARS become available there will be less impact of the allocation on total penalty-weighted delay.

APPENDIX A. C2 FACS BASED ON 1ST MEB EXAMPLE FOR TACTICAL NETS

1.) 1ST MEB COMMAND ELEMENT (MB CE)
   1) COC
   2) IC
   3) COMCON

2.) DIRECT AIR SUPPORT CENTER—
   1) DASC

3.) 3RD MAR REGT GROUND COMBAT ELEMENT
   1) COC
   2) IC
   3) COMCON
   4) FSCC

4.) BN 1/3, 2/3 & 3/3 COMMAND POST
   1) COC
   2) FC
   3) COMCON

5.) A, B, & C COMPANY OF 1/3 MARINES
   1) CP

6.) ARTILLERY BN
   1) FDC

7.) 5/11 SP ARTILLERY
   1) FDC

8.) FORWARD OBSERVERS
   1) FO

9.) A COMPANY TANKS
   1) CP

10.) B COMPANY TRACKS
   1) CP

APPENDIX B. TACTICAL NETS FOR 1ST MEB EXAMPLE

NET	NET NAME
1	MEB TAC1
2	MEB CSS
3	MEB COMM COORD
5	RADIO BN CRITICOMM
6	ECM CONTROL
7	3D MAR CMD
8	3D MAR TAC
9	3D MAR INTEL
10	3D MAR COMM COORD
11	3D MAR FSC
12	1/12 COF
13	1/12 CMD
14	1/12 FD
15	TAR/HR
16	MED BN EVAC COORD AIR
17	1/3 TAC1
18	1/3 MORTAR
19	1/3 TACP LOCAL
20	A1/12 COF
21	2/3 TAC1
22	2/3 MORTAR
23	2/3 TACP LOCAL
24	B1/12 COF
25	3/3 TAC1
26	3/3 MORTAR
27	3/3 TACP LOCAL
28	C1/12 COF
29	A1/12 CMD
30	B1/12 CMD
31	C1/12 CMD
32	N5/11 COF
33	COA CMD
34	1ST PLT CO A CMD
35	2D PLT CO A CMD
36	3D PLT CO A CMD
37	CO B CMD
38	1ST PLT CO B CMD
39	2D PLT CO B CMD
40	3D PLT CO B CMD
41	3TH PLT CO B CMD

APPENDIX C. C2FACS AND THEIR TACTICAL NETS

EXAMPLE BASED ON 1ST MEB

1ST MEB COMMAND ELEMENT (MEB CE)
COC—MEB TACTICAL (TAC) NET
COC—MEB COMBAT SERVICE SUPPORT (CSS)
COMCON—MEB COMMUNICATION COORDINATION (COMM)
IC—ECM CONTROL

A12 COMBAT ELEMENT (ACE) DIRECT AIR SUPPORT CENTER (DASC)
DASC—TACTICAL AIR REQUEST/HELO REQUEST (TAR/HR)
DASC—MECIAL BN EVACUATION COORDINATION

GROUND COMBAT ELEMENT (GCE)—3RD MARINE INF REGIMENT
COC—MEB TAC NET
COMCON—MEB COMM
COC—3RD MARINE COMMAND (CMD)
COC—3RD MARINE TAC
IC—3RD MARINE INTEL
FSCC—3RD MARINE FIRE SUPPORT COORDINATION (FSC)
FSCC—1ST BN 12TH MARINE ARTILLERY REGT CONDUCT OF FIRE (COF)
FSCC—1ST BN 12TH MARINE ARTILLERY REGT CMD
FSCC—1ST BN 12TH MARINE ARTILLERY REGT FIRE DIRECTION (FD)

1/3 BATTALION COMMAND POST (BN CP)—SIMILARLY FOR 2/3, 3/3
COC—3RD MARINE CMD NET
COC—3RD MARINE TAC
IC—3RD MARINE INTELLIGENCE (INT)
COMCON—3RD MARINE COMM
FSCC—3RD MARINE FSC
COC—1/3 MARINE TAC
FSCC—MORTAR
FSCC—TACTICAL AIR CONTROL PARTY LOCAL (TACP)
FSCC—BN COF
FSCC—BATTERY COF
FSCC—TAR/HR

A 1/3 COMPANY—SIMILARLY B AND C COMPANIES FOR EACH BN
COC—BN TAC

ARTILLERY BATTALION 1/12
FDC—INFANTRY REGIMENT FIRE SUPPORT COORD (FSC)
FDC—BN COF

FDC—BN CMD
FDC—FD
FDC—A 1/12 COF
FDC—B 1/12 COF
FDC—C 1/12 COF

A BATTERY 1/12
FDC—1/12 BN COF
FDC—1/12 CMD
FDC—1/12 FD
FDC—A 1/12 CMD
FDC—A 1/12 COF

A RIFLE COMPANY FORWARD OBSERVER—SIMILARLY FOR B AND C FO 1/12
FO—1/12 BN COF
FO—A 1/12 COF

N 5/11 SP ARTILLERY
FDC—2/3 TAC
FDC—1/12 COF
FDC—1/12 CMD
FDC—1/12 FD
FDC—N 5/11 CMD

A COMPANY 1ST TANKS—SIMILARLY B COMPANY TRACKS
CP—A COMPANY CMD
CP—1/2 TAC

1ST PLATOON A COMPANY—SIMILARLY 2ND AND 3RD PLATOON
CP—A COMPANY CMD
CP—1ST PLATOON CMD

APPENDIX D. TIME-LATE PENALTIES FOR BOSTS

The delay in performance of individual Basic Operational SubTasks (BOSTs) from jamming or simply because of traffic may have differing effects on performance of the Marine Corps missions depending upon the BOST. Delay of a reporting task will not directly cause lives to be lost but delay to a fire mission may. Therefore in aggregating total delay, the minutes of delay should be given differing weights in calculating a C3 measure of effectiveness based on timeliness. This appendix describes a set of relative weights or penalties for each of the BOSTs.

Before describing the results however it is noted that the BOSTs have been partitioned into those that are relevant to VHF single-channel nets and those that are not. This reduces the number of penalties to be determined. The BOSTs not considered are primarily the aviation and amphibious landing BOSTs that are performed with radios of other frequencies or higher capacities and are not candidates for SINCGARs. In addition the Combat Service Support (CSS) BOSTs are not considered (with the exception of the combat operations request for combat service support) in this baseline analysis.

The initial set of penalties for the SINCGARS relevant BOSTs are given in the accompanying table, Appendix D. They were estimated by relative judgments of the research team with a base penalty of 100 for the standard fire mission BOST under the call for force MBOT. Only a few BOSTs score higher than this. In general those BOSTs that involve execution of immediate fires have about 100 points and all others have lower penalties. Cooraination of

fire BOSTs have the next highest penalties, followed by planning and finally reporting which have values of 5 to 10 points. This leaves room for combat service support BOSTs to be added at a later date if desired.

The point scheme was designed to give an order of magnitude difference in ratio values between the most time critical and least time critical combat operations. We believe the order of penalties would not significantly vary between individual raters although the penalty ratio might vary.

The penalties in this appendix are for each minute of delay or time late. This could be measured from either initiation of the BOST or from some threshold time after initiation based on precedence (i.e. 10 minutes for FLASH messages) or other standard operating procedure or CEOI thresholds. It would also be possible to extend the penalty structure to include a one-time penalty for any delay above a threshold. This could provide additional discrimination between alternative allocations but would be dependent upon setting an acceptable threshold, which may be difficult to establish. If required, the one-time penalties could be established as a multiple of the penalties estimated above. The size of the multiple could be the same for each BOST somewhere in the range of a multiple of 10 to 100 or could vary by BOST category.

An additional hierarchical dimension to the penalties could be added to reflect relative importance of the BOSTs as a function of whether they were initiated by the platoon, company, battalion or brigade. With respect to fire mission it is unlikely that there is any difference in the importance of the message according to the command hierarchy. However for planning messages or orders it can be argued that delay moving down the chain of

command implies that many more units will be affected then by delay at the bottom of the chain. Therefore it may be desirable to introduce a factor to change some of the penalties based on command level. At this time the initiators of each BOST are not yet specified so this refinement must wait until data on frequencies of initiation of BOSTs by command level are known. It is likely that a BOST will ordinarily only be initiated by one level of command. The initial set of penalties then are shown in Appendix D as penalties per minute of delay from initiation of the BOST.

MULTIPLE AGENCY MESSAGE EXCHANGE SEQUENCES
MISSION AREA—MBOT—BOST COMBINATIONS

	VHF RELEVANT	..ATIVE PENALTY
Air Operations		
Offensive Air Support		
Close Air Support—Preplanned Mission	no	-
Close Air Support—Immediate Mission	no	-
Antiair Warfare		
Passive Air Defense	no	-
Active Air Defense	no	-
Assault Support		
Air Logistics Support	no	-
Search and Rescue	no	-
Control of Aircraft and Missions		
Employment of Aviation Assets	no	-
Airspace and Air Traffic Control	no	-
Intelligence		
Intelligence Planning and Direction		
Determine Requirements	no	-
Collection Planning	no	-
Collection Orders and Requests	yes	55
Intelligence Collection		
Signals Intelligence	no	-
Surveillance and Reconnaissance	no	-
Intelligence Dissemination		
Intelligence Reports	yes	60
Intelligence Summary	no	-
Target Intelligence Report	yes	80
Electronic Warfare		
Requests EW Support	yes	80
Tasks EW Support	yes	80
Combat Operations		
Warfighting Plans and Orders		
Submit MAGTF Operational Planning Data	yes	5
Submit GCE Operational Planning Data	yes	5
Submit ACE Operational Planning Data	no	-
Submit CSSE Operational Planning Data	yes	10
Develop and Distribute MAGTF Operation Plans and Orders	yes	10
Develop and Distribute GCE Operation Plans and Orders	no	-
Develop and Distribute ACE Operation Plans and Orders	no	-
Develop and Distribute CSSE Operation Plans and Orders	no	-
warfighting Ship to Shore Operations		
Advise Navy Control Organization		
Report Ship to Shore Movement		
Advise Helicopter Control Agencies		
Coordinate Personnel and Equipment Transfers		
Coordinate Supply Build-up		
Coordinate Beach Party Activities		
Receive and Report Serial Status		
Receive and Report Landing of Scheduled Waves		
Receive and Report Serial Records		
Submit Ship Disposition Reports		
Warfighting Communication Procedures		
Communication System Adjustment		
Coordinate Communication System Troubleshooting	yes	60
Submit Communication Systems Update	yes	80
Supervise Technical Coordination	yes	20

	VHF RELEVANT	RELATIVE PENALTY
Combat Operations		
Warfighting Operations		
Receive and Distribute Combat Data	yes	30
MAGTF Operational Reporting	yes	20
GCE Operational Reporting	yes	10
ACE Operational Reporting	no	10
CSSE Operational Reporting	no	-
Nuclear Event Reporting	yes	50
NBC Attack Reporting	yes	50
Request Additional Support	yes	45
Coordinate Combat Activities	yes	25
Coordinate RPV Activities	yes	25
Environmental Information	yes	20
Collect and Disseminate Weather Data	no	-
Fire Support		
Artillery Call for Fire		
Check Fire	yes	125
Counterfire Radar (CFR) Fire Mission	yes	130
Final Protective Fire (FPF) Adjustment	yes	150
High Angle Fire Mission	yes	100
High Burst/Mean Point of Impact Registration	yes	40
Precision Registration—FO	yes	40
Precision Registration—NAO/TAO	yes	80
Standard Fire Mission—FO	yes	100
Standard Fire Mission—Div Recon TM	yes	100
Standard Fire Mission—Meb Recon TM	yes	100
Standard Fire Mission—Meb RPV	yes	100
Standard Fire Mission—Mef Recon TM	yse	100
Standard Fire Mission—MEF RPV	yes	100
Standard Fire Mission—MEU Recon TM	yes	100
Standard Fire Mission—MEU RPV	yes	100
Standard Fire Mission—Regiment Artillery Obs TM	yes	100
Suppression Fire	yes	40
Call for and Adjust Fire—NAO/TAO	yes	100
Close Air Support (CAS		
Immediate Mission—FAC	yes	120
Control CAS—NAO/TAO	yes	120
Preplanned on-call Mission—FAC	yes	80
Preplanned Scheduled Mission—FAC	yes	80
Preplanned Scheduled Mission—ASRT	yes	80
Close-in Fire Support (CIFS)		
Immediate Mission—FAC	yes	140
Preplanned on-call Mission—FAC	yes	100
Preplanned Scheduled Mission—FAC	yes	100
Fire Planning		
Coordinate Subordinate C2FAC Activities	yes	25
Disseminate Coordination and Control Measures	yes	25
Establish Coordination and Control Measures	yes	25
Establish Target Processing Center	no	-
Position Naval Gunfire Radar Beacon Team	yes	25
Request Allocation of Additional Fire Support	yes	30
Request Supporting Arms Support	yes	35
Resolve Fire Support Coordination Problems	yes	30
Resolve Fire Support Conflicts	yes	30
Tactical Alerts	no	-
Target Assignment	yes	20
Target Intelligence Acquisition	no	-
Fire Support Reporting		
Aerial Recon Reports	no	-
Counterfire Radar Section Location Report	yes	20
Fire Direction Center Reports	yes	10
Meteorological (Met) Reports	yes	5

	VHF RELEVANT	RELATIVE PENALTY
Fire Support		
Fire Support Reporting		
Naval Gunfire Radar Beacon Team Location Report	yes	10
Observer/Controller Reports	yes	5
Supporting Arms Reports	yes	5
Survey Reports	yes	10
Shelling Report (SHELREP)	yes	15
Mortar Call for Fire		
Registration Mission	yes	40
Standard Fire Mission	yes	100
Naval Gunfire (NGF) Call for Fire		
Direct Support Naval Gunfire Mission	no	-
Direct Support Naval Gunfire Mission—RVP	no	-
General Support Naval Gunfire Mission	no	-
Massed Fires	no	-

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